THE · SOCIETY · OF · ENGINEERS

SOCIETY
OF ENGINEERS
FOUNDED 1854.

CIVIL & MECHANICAL
ENGINEERS' SOCIETY
ESTABLISHED 1859.

AMALGAMATED
· AND ·

* INCORPORATED · 1910 *

F. G. BLOYD,

President, 1911.

(*See p.* 33.)

(THE)

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SOCIETY OF ENGINEERS: ESTABLISHED MAY, 1854 } AMALGAMATED AND
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Journal and

TRANSACTIONS FOR 1911.

EDITED BY

A. S. E. ACKERMANN, B.Sc.(Eng.),
A.C.G.I., A.M.Inst.C.E., M.R.S.I.
SECRETARY.

LONDON:
PUBLISHED BY THE SOCIETY OF ENGINEERS
(INCORPORATED),
17, VICTORIA STREET, WESTMINSTER, S.W.
1911.

The Society is not responsible either for the statements made or for the opinions expressed in the papers or in the discussions thereon.

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THE INSTITUTION OF ELECTRICAL ENGINEERS,
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PAPERS AND PREMIUMS.

The Council of The Society of Engineers invite original communications from members, as well as from gentlemen who do not belong to the Society, on subjects connected with any branch of Engineering.

For any papers published in the Journal that may be considered sufficiently meritorious the Council may at their discretion award one or more of the following Premiums, viz. :—

1. The President's Gold Medal, of the value of Five Guineas, given annually by the President.
2. The Bessemer Premium, provided for annually by the late Sir Henry Bessemer, F.R.S., Honorary Member, of the value of Five Guineas.
3. The William Clarke Prize, provided by Mr. William Clarke, M.Inst.C.E., Hon.F.S.E., for past members of the Civil and Mechanical Engineers' Society; value Five Guineas.
4. The Nursey Premium, value Three Guineas, founded as a memorial to the late Perry F. Nursey.
5. The Bernays Premium, value Three Guineas, provided by the late Joseph Bernays.
6. The Society's Premiums, given annually by the Society, of an aggregate value not exceeding Twenty Pounds.
7. The Status Prize (see opposite page).

The number and value of the Society's Premiums are decided by the Council according to the number of meritorious papers published during the year.

Members of Council are disqualified by the provisions of the By-Laws from receiving Premiums.

THE STATUS PRIZE.

The Status Prize may be awarded by the Council each year for the next three years ending 1913 (if papers of sufficient merit are received) for the best paper written by any person on the subject of "How to Improve the Status of Engineers and Engineering, with special reference to Consulting Engineers." The prize for the year 1911 will consist of books and/or instruments, selected by the author of the premiated essay, to the value of six guineas.

The essay shall be written in the third person, shall contain not fewer than 4,000 nor more than 6,000 words, and shall be typed on one side only of foolscap paper, the distance between the lines being $\frac{3}{8}$ inch or more.

All essays submitted in competition for this prize and the copyright therein shall become the property of the Society, but the donor also shall have the right of publishing such essays or any part thereof.

The Council of the Society may, at their discretion, permit the publication of any essay by its author, on such conditions as they may think fit to require.

The premiated essay shall be read and discussed at a meeting of the Society, the reading being done by the author if possible, and such essay shall be published in the usual manner in the Society's Journal, the author being entitled to receive 50 copies of his paper upon publication thereof.

The prize shall not be awarded to any Member of Council or Officer of the Society.

Essays sent in for competition must be received by the Secretary on or before May 31st, in each year.

SIR JOHN AIRD.

The Society will hear with regret of the death of one of their members whose name is familar not only in engineering circles but to the general public. Sir John Aird, who died on January 6th, 1911, had been a member of the old Society of Engineers since 1855 and was one of the first to transfer his membership to the incorporated Society; an indication of the interest he took, even at an advanced age, in all matters with which he had to do.

A typical Scotchman, although a Londoner by birth, Mr. Aird became at the age of 18 assistant to his father, Mr. John Aird, of Ross-shire, who from humble beginnings had built up an important business as a contractor and was at that time engaged in the erection of the Great Exhibition Building (now the Crystal Palace) in Hyde Park. Subsequently he took part in the construction of waterworks and other public improvements in some of the principal continental cities and abroad, while later still his firm was responsible for the construction of the Metropolitan and St. John's Wood Railway and parts of the District Railway, in addition to extensions to the London Docks and many other works of an important character.

The great work with which Sir John Aird's name will always be linked was the construction of the great Nile dam at Assuan. This immense and extremely important enterprise was strongly recommended by Sir Benjamin Baker and other engineers and favoured by Lord Cromer, but the French Government opposed the necessary expenditure. It was then that Sir John Aird made the daring offer to build the dam at his own risk for £5,000,000 sterling, no payment to be made until after the dam was completed and the settlement then to be over a term of years.

This gigantic undertaking was satisfactorily completed well within the time limit and has largely increased the fertility of Egypt, besides securing Lower Egypt against famine in years when the Nile is low, thus conferring lasting benefit on the country.

Sir John Aird represented North Paddington in the House of Commons from 1887 to 1906. In 1890 he was elected first mayor of the new-formed borough and received his baronetcy from Queen Victoria shortly afterwards. He is succeeded in the title by his eldest son Mr. John Aird.

18th January, 1911.

ANNUAL DINNER.

The first Annual Dinner of the Society of Engineers (Incorporated) was held on Wednesday, January 18th, 1911, at the Criterion Restaurant, and was well attended. The chair was occupied by Mr. Diogo A. Symons, M.Inst.C.E., the retiring President, and the guests included Mr. Alexander Siemens, President of the Institution of Civil Engineers ; Col. Sir. Edward Raban, K.C.B., R.E. ; Prof. C. Vernon Boys, F.R.S. ; Mr. Wm. Clarke, M.Inst.C.E. ; Mr. Leslie R. Vigers, President of the Surveyors' Institution ; Mr. E. P. Frost, President of the Aeronautical Society, and a number of ladies. The following were among the members present :—Messrs. J. W. Wilson, Percy Griffith, E. J. Silcock, W. B. Esson, N. Scorgie, H. P. Maybury, J. F. J. Reynolds, Henry C. Adams, S. Cowper Coles, C. T. Walrond, P. G. Scott, and A. S. E. Ackermann (Secretary).

After the loyal toasts had been honoured, Col. Sir Edward Raban proposed the toast of "Applied Science," to which Prof. C. Vernon Boys, replying, said that he was equally in sympathy with the man of pure science and the man of applied science, and realised the difficulties with which the latter had to contend. The man of pure science had a comparatively simple problem from which adventitious matters were as far as possible excluded, but the man of applied science was continually wrestling with adventitious things ; but each was necessary to the other. The relation between pure and applied science was admirably illustrated by wireless telegraphy, in the development of which they had the most marvellous pure science in the work of Maxwell and Hertz at one end, and the applied science of Marconi at the other.

Mr. J. W. Wilson, proposing "Kindred Institutions," remarked that the phrase suggested the reduction of all societies to one. A year ago the Society of Engineers and the Civil and Mechanical Engineers' Society had wedded and become one. He suggested that they might have a comprehensive membership ticket entitling a man to belong to all kindred institutions.

Mr. Alexander Siemens, replying, said that he found fault with the terms "pure" and "applied" science. Two thousand five hundred years ago Aristotle defined science as the faculty of demonstrating necessary conclusions from necessary premises,

and art as the trained faculty of producing, involving sound reasoning. Similarly, he would say that applied science was science and the other was not. Engineers, he would say, were the real civilised people, and all the others were no better than they were 2,500 years ago. "Kindred Institutions," therefore, comprised all the others.

Mr. Percy Griffith submitted "The Ladies," and Mr. E. J. Silcock replied on their behalf.

An excellent programme of music, under the direction of Mr. Charles Capper, terminated a most enjoyable evening.

NITROGEN PRODUCTS MADE WITH THE AID OF ELECTRIC POWER.

By ERNEST KILBURN SCOTT, M.I.E.E., A.M.Inst.C.E.

ALTHOUGH electric power has only been used for about 6 years in the manufacture of Nitrogenous products very great strides have been made, and some developments are now in hand in Norway which are quite startling in their magnitude.

The following are some of the products produced either directly or indirectly from atmospheric Nitrogen with the aid of electric power.

TABLE I.—NITROGENOUS PRODUCTS MADE FROM ATMOSPHERIC NITROGEN FIXED BY ELECTRIC POWER.

	Chemical Symbol.	Nitrogen Content. Per cent.	Uses.
Nitric Acid ..	HNO_3	Pure 22·2 ·95 21·1	For manufacture of explosives, dynamite, guncotton, smokeless powder, etc.
Calcium Nitrate, Nitrate of Lime, or Norwegian Saltpetre	$Ca(NO_3)_2\,4H_2O$	Pure 17·1 Manure 13·0	For various chemical purposes and as a manure.
Sodium Nitrite ..	$NaNO_2$	—	For making azo dyes, etc.
Calcium Nitrite ..	$Ca(NO_2)_2$	18·0	A possible competitor of Nitrate of Lime as a manure.
Ammonium Nitrate	NH_4NO_3	35·0	Made from above and used for blasting powders such as Roburite, etc.

As the principal oxides and acids of nitrogen and certain nitrites and nitrates are frequently referred to, it will be well to tabulate them and give the chemical symbols. (See Table II.)

TABLE II.—COMPOUNDS OF NITROGEN.

	Symbol.	Remarks.
Nitrous Oxide	N_2O	Laughing gas.
Nitric Oxide	NO	Colourless gas formed by electric discharge.
Nitrogen Trioxide	N_2O_3	
Nitrogen Peroxide	NO_2	Brown-red gas formed by oxidising NO
Nitrogen Pentoxide	N_2O_5	
Nitrous Acid	HNO_2	Unstable in aqueous solution.
Nitric Acid	HNO_3	Used for making explosives.
Sodium Nitrite	$NaNO_2$	Used for making dyes.
Sodium Nitrate	$NaNO_3$	Chili Saltpetre.
Calcium Nitrate	$Ca\ (NO_3)_2$	Norwegian Saltpetre.
Calcium Nitrite	$Ca\ (NO_2)_2$	A possible manure.

The first idea which experimenters had in mind, when trying to fix atmospheric nitrogen, was to make nitric acid. They soon found however that the process that could produce acids commercially, could also be utilized for making manure.

As there is a much greater market for artificial manures than for any other nitrogenous product the works in Norway and elsewhere are principally occupied in making such manures. Consequently a good deal of what follows is necessarily concerned with that phase of the question.

A few general observations on manures will therefore be useful as an introduction. Amongst the principal plant foods are phosphorus, potash, and nitrogen, and the last named is perhaps the most important as it is the principal constituent of the protoplasm of plants.

Nitrogen builds up our own muscular system for when we eat bread we are taking in nitrogen which formed the gluten in wheat. When we eat meat we are taking in fibrine which also is nitrogen. Without nitrogen, man is impossible and wherever there is life there are more or less complicated substances containing nitrogen as the carriers of life.

Now it happens that the main constituent of the atmosphere is this same element nitrogen, it being mixed with oxygen in the proportion of about 77 lb. and 23 lb. As a free gas, however, it cannot be taken up directly by plants.

Nature fixes it and introduces it into the soil in several ways and of course man has also learnt to introduce it by means of manures.

Electrical Discharge.

One natural way is by electrical discharge and another by bacteria. These have been at work right through the ages and it thus comes about that much of the virgin soil of the earth, as for example that of Western Canada, contains large stores of nitrogen. It is this natural store that enables so much wheat to be grown without adding manure to the soil, and it is indirectly the cause of the influx of farmers from the partly exhausted wheat areas of Western United States to the virgin soil of Canada.

Some day the Canadian soil will also have its natural stores of nitrogen exhausted by continual cropping of wheat, and then manure will have to be added just as in the other parts of the world, where agriculture has been carried on for generations.

Electrical discharge is going on all the time and in some parts of the world more than others. For example in this country it is estimated that each acre receives 10 lb. of nitrogen per annum from this source. In Egypt, where thunderstorms and rain are infrequent, the gain of nitrogen is very small, whereas in some tropical countries it is much more than 10 lb. In Ottawa it is 6 to 8 lb.

Bacteria.

The Bacterial method is the base idea of rotation of crops, which has been known from the Roman times to be specially valuable for increasing plant growth. The scientific explanation was however only given in 1866 when Hellreigel suggested that leguminous plants obtain nitrogen from the air by means of bacteria living in the root nodules of those plants. In 1898 Maze proved that such fixation of nitrogen did occur and later a culture of the particular bacteria was obtained by Beyerinck and named *Bacillus Radiucola*.

Professor Bottomley of King's College has done much valuable work in this direction and he has found that by mixing cultures of two different bacilli he can fix more nitrogen in a given amount of soil than the combined amount fixed by each bacillus tried separately.

Bacterial culture is not a manure, for what it does is to add organisms to the soil which breed and multiply on the roots of a

leguminous crop. They enable such plants to grow in a soil which contains little or no natural nitrogen. The poorer the soil, the more marked the effect.

In New South Wales, the writer has seen magnificent fruit grown on what we should call sand, and this was simply done by repeatedly planting vetches and peas and then ploughing them in. Dr. Greig Smith of Sydney is one of the best known workers on this subject of bacteria in the soil.

The writer has dealt with the question of bacteria at length because he wishes to make it clear that the mere addition of combined nitrogen to the soil is not the end of the matter. Bacteria are a most important link in the chain and are necessary in any event to pass the nitrogen into the plants. They may get it from the air or from natural or man-provided nitrogen placed in the soil.

Manures.

And now as to the nitrogen which man can place in the soil.

Stable Manure is the oldest method and for many years the farmers of this country have been able to obtain large quantities from omnibus and tramway companies, etc. The introduction of mechanically propelled vehicles has however almost stopped this source and even road sweepings have not the value they had because they are largely spoilt by tar and grease.

Guano, Fish, Offal are all used but the supply is very limited. Occasionally one hears of some new Island in the Pacific being exploited for its guano, but the farmers of the world require so much that the deposit is soon exhausted.

Shoddy has come into use of recent years and a good deal of it is used on the hop fields of Kent. Wool contains about 8% of ammonia but as everyone knows there is a good deal that is not wool in shoddy. In any case only cloth-manufacturing countries like ours can produce shoddy.

Sulphate of Ammonia was the first artificial manure to be used for introducing nitrogen to the soil and a good deal is used in this country and exported for the purpose. As we adopt more rational ways of utilising our coal supplies than by wastefully burning them in boiler grates and on domestic hearths the greater quantities will be made. Table III. shows that the output from coke ovens and producer-gas plants is increasing, although it is still a much smaller amount than that made in gas works.

When we consider that the most up-to-date sulphate of ammonia plant only recovers about 15% of the nitrogen in the coal it will be seen that there is much room for improvement.

In this connection it is interesting to note that in using sulphate of ammonia as a manure we are using the supply of nitrogen which the organic life of an earlier epoch has stored up. In a

sense, therefore, we are doing almost the same thing as the farmers in Canada when they exploit the nitrogen in virgin soil.

TABLE III.—SULPHATE OF AMMONIA PRODUCED IN THE UNITED KINGDOM.

	1906.	1907.	1908.
	Tons.	Tons.	Tons.
Gas Works	157,160	165,474	165,218
Iron ,, ...	21,284	21,024	18,131
Shale ,, ...	48,534	51,338	53,628
Coke Ovens	43,677	53,572	64,227
Producer Gas	18,736	21,873	24,024

Sodium Nitrate or Chili saltpetre is the principal source of nitrogen for the world's wheat crop. As this is also a natural deposit we are again using up a supply which like that of our coal fields and virgin soil must sooner or later come to an end.

In the case of sodum nitrate the end is in sight, because although searches have been made elsewhere the Chilian deposit is practically the only one available. The caliche, as it is called, is found in layers 2 to 12 feet thick and it contains 15% to 65% of nitrate of soda. After refining the content is 95%.

The first shipload sent to Europe in 1825 was thrown away as useless, for no one would buy it, but since then the consumption has gone up at an enormous rate. (See Table IV.)

TABLE IV.—OUTPUT OF CHILI NITRATE.

In year 1830	935 tons.
,, 1850	50,000 ,,
,, 1870	220,000 ,,
,, 1890	1,050,000 ,,
,, 1907	1,740,000 ,,
,, 1908	2,200,000 ,,

By plotting these figures on a curve and continuing the curve at the same slope it would appear probable that by 1915 the world's consumption of sodium nitrate will have reached the enormous total of about 10,000,000 tons per annum, worth about 90 million pounds sterling. Seeing that each acre of the earth's surface has over it about 30,000 tons of nitrogen it seems rather

foolish to send 10,000 miles for our nitrogen. As we shall see, this will not be necessary because certain electrical engineers and chemists have solved the problem of fixing it wherever there is cheap power.

Regarding the extent of the deposits in Chili, the Chilian Government issued a report in 1907 from which the following is extracted :—"In 1892, the land which had been explored and "sampled up to date, was estimated to give 140 million tons. "Of this 140 million tons, 20 million have been exported during "the period of 15 years which have since elapsed. The surface "in the hands of private companies in Tarapaca covers an area of "59 sq. kilometres, each of which is estimated to yield an average "of 90,000 tons. The lots of fiscal grounds measured, bored "and estimated in Tarapaca cover an area of 59 sq. kilometres, "containing six million tons of nitrate. In the province of "Antofagasta, 3,780 sq. kilometres have been measured. In "round numbers there is a total quantity of 186 million tons of "nitrate. Thus we get a total minimum stock of 220 million "tons."

Of course the deposits which are easily reached and worked are naturally the first to be used up, so that as time goes on the cost of producing the nitrate will tend to increase. Further if those interested in Chilian nitrate were to find themselves the holders of an absolute world monoply, this also would cause the prices to increase. As a matter of fact some few years ago there was a tendency for prices to rise, but the introduction of manures made by electric power materially helped to steady them.

Sir William Crookes* did a great service in 1898 when he uttered his famous warning of a nitrogen famine, and pointed out that the virgin soils of the world were being rapidly exhausted of their natural stores of nitrogen, by continual cropping of wheat, without putting in manure. He said "starvation might be averted through the laboratory," and so it has turned out, for both nitrate of lime and calcium cyanimide have proved to be excellent manures.

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* In 1898 Sir William Crookes said :—"When provision shall have been made, if possible, to feed 230,000,000 units likely to be added to the bread-eating populations by 1931 by the complete occupancy of the arable areas of the temperate zone now partially occupied—where can be grown the additional 330,000,000 bushels of wheat required ten years later by a hungry world ? What is to happen if the present rate of population be maintained, and if arable areas of sufficient extent cannot be adapted and made contributory to the subsistence of so great a host ? If bread fails, not only us, but all the breadwinners of the world—what are we and they to do ?"

Again, in his "Essay on the Wheat Problem" :—"The fixation of atmospheric nitrogen is one of the greatest discoveries awaiting the ingenuity of chemists. It is certainly deeply important in its practical bearings on the future welfare and happiness of the civilised races of mankind."

CHRONOLOGY.

A brief chronology will help to show the sequence of events that led up to the manufacture of nitrate of lime.

1773.—Dr. Priestley, the discoverer of dephlogisticated air or oxygen, succeeded in combining the nitrogen and oxygen of the air by means of a series of electric sparks passed between terminals in a closed glass jar.

1780.—Cavendish working on similar lines made nitric acid by bringing the brown-red coloured gas nitric peroxide into contact with water.

1831.—Michael Faraday discovered the principle of electro-magnetic induction, and this as we shall see later was of distinct value in connection with the first manufacture of nitrate of lime.

1846.—Bunsen and Kolbe noticed that nitric acid was formed when they exploded oxy-hydrogen gas. They further observed that the higher the temperature the more nitric acid they obtained.

1859.—Newton and Le Febre took out patents for use of electricity in causing the union of nitrogen and oxygen.

1861.—Plucker found that when a high-tension discharge passed between electrodes situated in a magnetic field a disc of sparks resulted.

1865.—Dr. Liebig founded the science of agricultural chemistry and showed that mineral food was being continually taken from the ground by plants. He said that by the addition of bodies containing nitrogen to the soil an essential requirement of plant life was met.*

1879.—Sir William Siemens invented the electric arc furnace and so obtained temperatures much higher than any previously obtained.

1885.—Spottiswoode and Dewar produced and studied the action of electric flames in air.

1892.—Sir William Crookes exhibited at a Royal Society's Soirée an experiment showing an arc flame which produced nitrous and nitric acid.

1894.—Naville and Guye enunciated the theory that the yield of nitric oxide is notably increased by placing electrodes in the narrow part of the furnace, and after submitting

* Liebig also said :—" Both the rise and decline of nations are governed by the same law of Nature. The deprivation of the soil of the conditions of fruitfulness brings about their decline, while the maintenance of such conditions leads to their permanence, prosperity and power. The nation is not fed by peace nor destroyed by war—these conditions only exercise a temporary influence on it. It is the soil on which man builds his home which is instrumental in holding human society together or dispersing it, and in causing nations and empires to disappear, or become powerful. The absolute fruitfulness of the ground is independent of mankind, but he possesses the power of diminishing or prolonging such fruitfulness."

the gas to the action of electricity, drawing it off as quickly as possible.

1897.—Lord Rayleigh published his "Observations on the Oxidation of Nitrogen Gas," and succeeded in keeping an electric flame burning, of more than 1 h.p. He also showed that 1 k.w. hour would produce 50 grammes of nitric acid.

1898.—Sir William Crookes gave his warning regarding the exhaustion of nitrogen, and his equally famous prophecy of how a nitrogen famine might be averted.

1898.—Lehmann developed Plucker's experiment of 1861 and with the help of a magnetic field suitably placed, obtained a spreading arc flame.

1899.—Elihu Thompson used the magnetic field for suppressing arcing in lightning arresters and tramcar controllers.

1899.—MacDougall* and Howles made some costly experiments in England with a view to commercial manufacture of nitric acid. They produced it at the rate of 300 kilograms per k.w. year.

1902.—Bradley and Lovejoy constructed an apparatus at Niagara which gave 414,000 small arcs per minute between platinum points. They used direct current at 9,000 volts and produced nitric acid but not at a commercial price.

1903.—Muthmann and Hofer investigated the effect on air in various parts of the arc flame, and they obtained a maximum concentration of 6·7% nitric oxide from the air passed through.

1903.—De Kowalski and Moscicki exposed air to an alternating current arc at 50,000 volts and 6,000 to 10,000 periods per second. The production of nitric acid is said to have been at the rate of 440 kilograms per k.w. year.

1903.—Professor Birkeland and S. Eyde built an electric furnace in which they obtained a disc flame arc several feet in diameter by means of alternating current at 5,000 volts passing across a magnetic field.

1904.—The Notodden factory for fixation of nitrogen on Birkeland-Eyde process was started.

1905.—Nernst studied the question of how much nitric oxide was produced at various temperatures. He showed that under normal conditions when air is passed through an electric arc at 3,200 deg. C. the nitric oxide could not exceed 5%.

1905.—Dr. Schönherr invented the tube furnace and developed it with the assistance of the Badische Anilin and Soda Fabrik.

* The writer of this paper helped Mr. MacDougall to make some experiments in 1899, at Messrs. Johnson and Phillip's works.

Theory of Fixation of Nitrogen.

The theory of the formation of nitric oxide in the electric arc has been investigated by Professor Nernst and others. When air passes through an arc equal volumes of nitrogen and oxygen combine to form the colourless gas nitric oxide, and the amount formed is always very small compared with the amount of air. As will be seen from Table V., Professor Nernst says it only amounts to 5% at 3,327 deg. C., which is the temperature of the hottest part of an electric arc.

TABLE V.—Percentage of Nitric Oxide formed at Various Temperatures.

At an absolute temperature of ——degrees Cent.	Difference in degrees Cent.	Percentage of Nitric Oxide formed.
1500	428	0.1
1928		0.5
2202	—	1.0
2403	—	1.5
2571	—	2.0
2854	—	3.0
3103	224	4.0
3327		5.0

From this Table V. it will be seen that for a difference in temperature of 428 deg. C. (to 1,928 deg. C.) the extra yield is 0·4%; whereas for a difference of only 224 deg. C. (to 3,327 deg. C.) the extra yield is 1·0%. Calculating the quantities of heat to produce these two temperatures, it will be found that five times as much heat is required for a given quatity of nitric oxide at 1,928 deg. C. as is required at 3,327 deg. C. Clearly, therefore, an arc flame at a temperature of at least 3,000 deg. C. should be the best temperature to use, and theoretically about 5% nitric oxide should be produced.

The actual amount turned out is much less than 5% because at the same time that the nitrogen and oxygen combine, some of the resulting nitric oxide also dissociates because of the heat. To keep as much of it as possible in the combined state it has to be immediately cooled. Most of the cooling is effected automatically by the excess of air, and by so constructing the furnace that

the fixed gas is at once removed from the region of intense heat. It should be mentioned also that as decomposition falls off very rapidly with dilution, the large extra amount of air that has to pass through the furnace and be heated up is of advantage in keeping the nitrogen in a fixed state.

In the Birkeland-Eyde furnace only about 1% of the air is fixed, and in the Schönherr arc, it is not more than 2%.

In 1905 Hofer calculated that one k.w. year (of 365 days and 24 hours a day) should yield, theoretically, the following amounts of nitric acid by direct fixation :—

Arc at		Kilogrammes.
4,200 deg. C.	.. ..	1,850
3,200 ,, C.	.. ..	819

Although it would appear that the great heat of the electric arc is necessary for the production of nitric oxide in quantity, yet at the same time it is well known that a silent electric discharge will also form the gas. For example :—The silent electric discharges between the windings of high-tension alternators and motors forms nitric oxide gas, and if moisture is present the resulting nitric acid may burn the insulation, etc. A distinct odour of ozone and nitrogen peroxide can be observed in any of the large electric power stations and sub-stations where pressures of 11,000 volts or more are used.

Warburg (see Zeit. Elektrochemie, 1906, 12,540) has expressed the opinion that the kinetic energy of the gases produced by the electric discharge is directly used in the formation of nitric oxide before the state of heat equilibrium is reached.

The furnaces for direct fixation of nitrogen which the writer proposes to refer to are —

Bradley & Lovejoy.
Birkeland & Eyde.
Schönherr.
Pauling.

Bradley & Lovejoy's Apparatus

As used by the Atmospheric Products Co., it consisted of a stationary cylinder, 4ft. inside diameter and 4½ft. long, having a number of platinum points fixed on the inside. A drum mounted on a spindle rotated inside the cylinder and carried arms shod with platinum points. There were 23 zones of points, each zone having 6 points, and the points did not quite touch as the drum was rotated. The two sets of points were connected to a direct current supply at 9,000 volts and this was sufficient to strike the arcs when the points were closest together. As the drum rotated these arcs were drawn out and broken and the speed was

such that 414,000 separate arcs were made and broken per minute. Through the space between the drum and the fixed cylinder, air was blown and part of it was changed to nitric oxide.

The plant closed down in 1904. It was very expensive to make and maintain because of the platinum and the necessity of using direct current. Also the output of nitric acid was not large enough to enable the process to compete commercially.

The Birkeland-Eyde Furnace.

The Birkeland-Eyde Magnetic Arc Furnace as installed at Notodden is shown in Fig. 1. It consists of a circular sheet steel drum about 8ft. in diameter and 2ft. wide lined with refractory fire-brick and having a disc-like space in the centre, 6½ft. diameter and 1¼ inches wide.

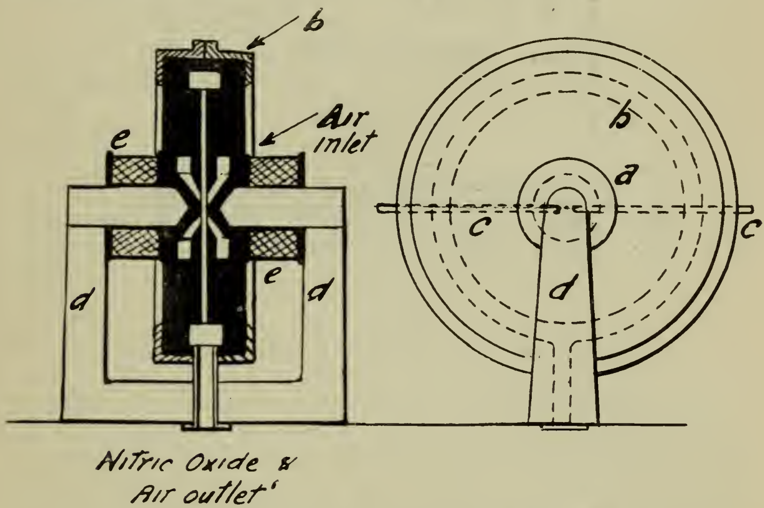


Fig. 1. Birkeland-Eyde Furnace with Magnetic Field.

Air holes *a* direct an evenly distributed supply at the centre of the furnace and a Roots blower gives a gentle pressure to the air. The channel *b* round the periphery of the disc space carries off the nitrous oxide and nitric oxide gases as well as unoxidised air.

Electrodes *c c*, Fig. 1, project into the centre of the furnace and approach within about ⅓rd of an inch. They are hollow copper tubes 6in. diameter and ⅜in. thick, and water circulates through to keep them cool. The points of the electrodes lie in a strong magnetic field set up by the field magnet *d*, and the two coils *e e* are placed close up to the pole pieces so as to reduce magnetic leakage as much as possible. The magnetic field

between the poles is about 4,500 magnetic lines of force per square centimetre.

Alternating current at 5,000 volts 50 periods per second is supplied to the electrodes whilst of course direct current flows round the field coils. The flame starts with the formation of a short arc between the electrodes, and being easily deflected by the magnetic field, the arc immediately moves in a direction perpendicular to the lines of force. It moves to one side, just as would any other moveable conductor, in accordance with the law discovered by Michael Faraday.

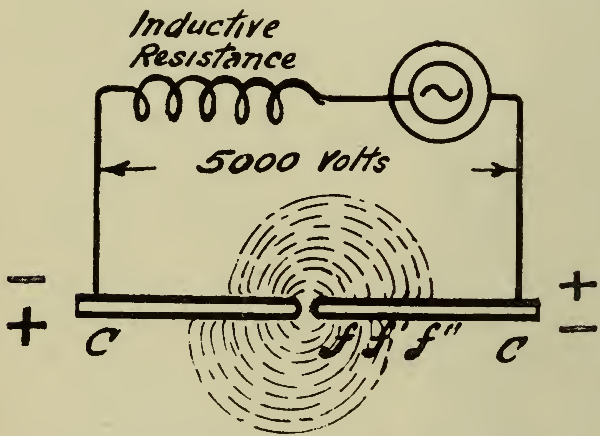


FIG. 2. DIAGRAM OF BIRKELAND-EYDE FURNACE.

The extremities of the arc retire along the electrodes, as shown in Fig. 2 at $f\ f'\ f''$, and as it increases in length its resisttance also increases. The tension is thus heightened until it becomes sufficient to strike a new arc across the points of the electrodes *c c*. Now as the resistance of this short arc is very small the tension of the electrodes suddenly sinks to a point which will not sustain the long arc and it is thus extinguished. It will be readily seen that an inductive resistance, Fig. 2, is a very necessary piece of apparatus to have in series with the arc. The self-induction effects a displacement of phase according to the currents flowing and this enables the arc to burn steadily. The power factor being lowered it is necessary to make due allowance when estimating sizes of alternators and cables.

One interesting point is that the flame extends farther along the positive electrode than along the negative, and the explanation of this phenomenon appears to be as follows.

When looked at through coloured glasses the extremities of the arc appear like glowing spots upon the sides of the electrode.

The glowing spots on the positive electrode are small, and lie very close together; while those on the negative electrode are larger, and lie farther apart.

The reason for these spots appears to be that the arcs solder themselves, so to speak, to the electrodes, and the magnetic force is only able to make the extremities of the arcs move along in tiny leaps. For some reason the extremities of the arc cling more closely to the negative than to the positive electrode, and, therefore, the flame extends farther along the positive electrode than along the negative as is shown in Fig. 2.

When the flame is burning it emits a loud noise, from which the furnace attendant can judge roughly the number of arcs formed per second. This has been investigated by the aid of an oscillagraph, and the E.M.F. and current curves are shown in Fig. 3.

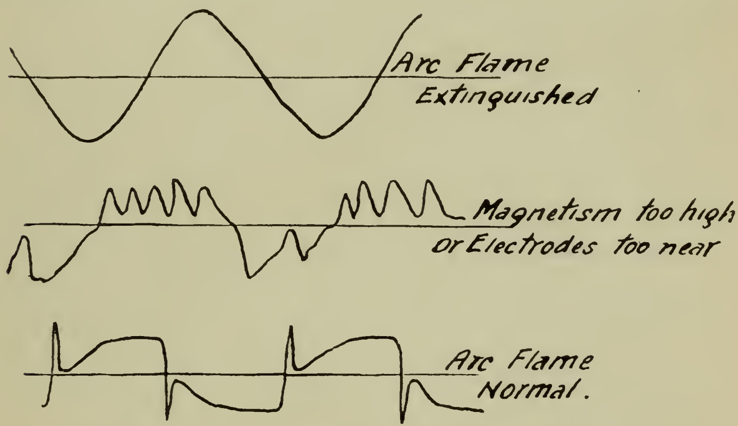


FIG. 3. E.M.F. CURVES WITH BIRKELAND-EYDE FURNACE.

The jagged E.M.F. curve is given with the disc flame in operation, while the comparatively regular sine curve is given when the electrodes are screwed so far from one another that the arc flame is extinguished.

As shown by the jagged curve there are several arcs at each reversal of the current, which gives a total of several hundred per second, and not merely $2 \times 50 = 100$ in accordance with the periodicity. The jagged curve occurs when the magnetism is too high, or the distance between the electrodes too small. For large, steady-burning flames, only one arc is formed at each reversal of the current, and this is the ideal aimed at.

The necessity of having alternating current applied to the electrodes will be appreciated from the fact for if direct current was employed the arc would be deflected to one side only. By

having each electrode alternatively positive and then negative the arc is blown out first to one side and then to the other, thus giving a disc of flame about 6ft. in diameter. As the speed at which the arc moves outwards is very rapid, and the formation of a new arc practically instantaneous, the arc appears to the eye as a constant sheet of flame.

The furnace of 1,000 h.p. costs with its inductive resistance and fittings about £1,000, but as a good deal of the expenditure would be common to any size of furnace, it is expected that the 2,000 k.w. furnace now being built will not cost more than £1,200.

The furnace works so steadily that it burns for weeks on end without any regulation worth mentioning, whilst at the same time its cost of maintenance is very low. Electrodes are changed and repaired every 300 hours, and the fireproof lining every fourth to sixth month. The temperature of the flame is about 3,500 deg. C. and the temperature of the escaping gases is between 800 and 1,000 deg.

At the Notodden Factory about 75,000 litres of air are treated per minute and the air contains about 1 per cent. of nitric oxide when it leaves the furnaces.

By the aid of Roots blowers, the air is blown into the centre of each furnace through tubes in the baseplate. The nitric oxide gas and unoxidised air pass into a channel built round the periphery of each furnace and thence into two fireproof-lined gas-collecting pipes, about 6ft. in diameter, lined with fire-brick. These pipes convey the gas to four steam boilers, where the temperature is much reduced, the heat given off by the gases being used to raise steam for concentrating the products and for driving the air compressors for pumping the acids and soda. The gases then go through tubes in the evaporating tanks. This brings the temperature down to about 200 to 250 deg. C.

The temperature is lowered still further, to 50 deg. C., by passing it through a number of aluminium tubes over which cold water is flowing. The gas then enters the oxidation tanks, which are large vertical iron cylinders having acid-proof linings. The gas stays here some time and gradually takes up oxygen and forms nitrogen peroxide, the percentages being now about 98% air and 2% nitrogen peroxide.

Absorption Towers.

The next process is to bring the nitrogen peroxide into contact with water to form nitric acid, and this is done in two series of towers each consisting of four. These towers are built of granite and are filled with broken quartz, this substance and the granite being chosen because they are not affected by acid. Each tower measures 2 metres square by 10 metres high and it has been found that they will give an absorption of 3·3 kilograms of nitric acid per cubic metre of space per 24 hours.

The gas and air enter the bottom of the first tower, travel up through the quartz, and then pass by an earthenware pipe to the top of the second tower. They travel down this and go to the bottom of the third tower and so on, aluminium fans being fitted on each tower to help the circulation. Dilute nitric acid slowly trickles down through the quartz, and this meeting the nitrogen peroxide gas absorbs a good deal of it.

The liquid moves from tower to tower in the opposite direction to the gas. Thus the fresh water enters at top of the fourth tower, it flows down through the interstices between the pieces of quartz and falls into a granite tank. From there it is pumped by compressed air to the top of the third tower, down which it trickles into another tank and from which it is pumped to the top of the second tower and so on. It is thus on the contra flow principle.

All this time the water has been absorbing the nitrogen peroxide gas so that when it reaches the bottom of the first tower it contains about 40% acid. The liquid in the tank at bottom of second tower contains 25%. that the at bottom of third tower 15% and that at the bottom of fourth tower 5%. As a matter of fact the actual chemical process of turning the gas into nitric acid is not quite so simple as it looks, because it first passes through the nitrous acid stage.

TABLE VI.—Chemical Equations.

In the electric furnace from 3,000 deg. C. down to 1,000 deg. C., nitric oxide, a colourless gas, is formed thus :—

(1.) $N_2 + O_2 = 2NO$ nitric oxide.

In the oxidation chambers, etc. from 500 deg. C. down to 50 deg. C., the red-brown gas nitrogen peroxide is formed thus :—

(2.) $2NO + O_2 = 2NO_2$ nitrogen peroxide.

In the four acid absorption towers the nitrogen peroxide combines with water to form nitric acid and nitrous acid thus :

(3.) $2NO_2 + H_2O = HNO + HNO_2$ nitrous acid.

As the nitrous acid is unstable in an aqueous solution it gives nitric acid and nitric oxide thus :—

(4.) $3HNO_2 = H_2O + HNO_3 + 2NO$ nitric oxide.

The nitric oxide then combines with more oxygen again to form nitrogen peroxide and equations (3) and (4) are repeated :—

(5.) $2NO + O_2 = 2NO_2$ nitrogen peroxide.

What is left of the nitrogen peroxide and nitric oxide gases pass to the fifth tower, when they meet sodium hydroxide and form sodium nitrite thus :—

(6.) $NO_2 + NO + 2NaOH = H_2O + 2NaNO$ sodium nitrite.

The nitric acid concentrated to 40% is sprayed on to calcium carbonate. It gives off carbon dioxide gas and forms calcium nitrate thus :—

(7.) $2HNO_3 + CaCO_3 = CO_2 + H_2O + Ca(NO_3)_2$ calcium nitrate.

When the nitric peroxide gas first comes in contact with the water and acid it forms the two acids nitric acid and nitrous acid as in equation (3). The nitrous acid then decomposes into nitric acid and nitric oxide as shown by equation (4) and this latter gas again oxidises to nitric peroxide, see equation (5). This meeting with more water forms again into nitric acid and nitrous acid and so the process goes until nearly all the nitrogen peroxide is absorbed.

It would only be possible to convert all the nitric oxide into nitric acid by having exceedingly large absorption towers and given plenty of time. Therefore, the last traces of the gas are removed by two alkaline towers as described under the heading sodium nitrite.

Nitric Acid.

Pure nitric acid is made by taking the 40% solution which is obtained by direct absorption and concentrating it up to 60% by distillation. Repeating the distillation with twice the weight of 92% sulphuric acid to take up the surplus water gives 98% nitric acid. During the process the sulphuric acid is reduced in strength to about 80% and it is then concentrated back again to 92% by heat from the furnace gases.

It may be noted that nitric acid can also be concentrated electrolytically, and the Salpetersäure Industrie Gesellschaft of Gelsenkirchen in Austria has such a process in operation.

Nitrate of Lime.

To make nitrate of lime the nitric acid of about 40% is collected from the cisterns and pumped to earthenware receivers over granite vats filled with limestone. The acid is distributed in jets on to the limestone and this drives off the carbonic acid with violent effervescence, see equation (7). The nitric acid takes its place and a watery solution of nitrate of lime or calcium nitrate is formed. This solution of nitrate of lime is now pumped into a vacuum evaporating apparatus, because by boiling in vacuum there is a great saving in the heat. The steam necessary for this evaporisation is obtained from the steam boilers, which as before mentioned are heated by waste heat of the furnace gases. The concentration of the nitrate solution in the evaporising plant is continued until the specific weight of the liquid at a given temperature shows a content of 13 % of nitrogen.

The solution is then pumped into solidification pans, under

which cold air is circulated to accelerate cooling and the nitrate of lime stiffens into a brittle, crystalline mass. This is broken up into lumps, which pass to ball crushing mills, where it is reduced to a granular state. The coarse powder is then raised by an elevator into a hopper, from the bottom of which it falls into barrels which hold 2 cwt. These barrels are lined with paper to guard against damp.

The colour varies somewhat with the colour of the limestone used.

When nitrate of lime is sold for chemical works it is simply run into thin iron drums and allowed to settle.*

The result is known commercially as nitrate of lime or Norwegian saltpetre, and contains 23% of water and various impurities as shown by the following analysis (see Table VII.).

TABLE VII.—Analysis of Commercial Nitrate of Lime.

		Per cent.
Calcium Oxide	CaO	25·83
Nitrogen	N	12·47
Water	H_2O	23·83
Carbon Dioxide	CO_2	0·52
Magnesium Oxide	MgO	0·41
Aluminium Trioxide..	Al_2O_3	0·71
Residue insoluble in Hydrochloric Acid..	—	0·51

With the Birkeland-Eyde process, one k.w. year gives 500 to 550 kilograms of nitric acid or 853 to 938 kilograms of nitrate of lime. The latter usually contains 13% of nitrogen which corresponds to 111 to 122 kilograms of combined nitrogen. It is guaranteed to contain 12¾% of nitrogen.

The best result at Notodden has been 900 kilograms of nitric acid per k.w. year measured at the arc terminal and allowing for 100% nitric acid.

Nitrate of lime can be bought for £7 15s. per ton of 20 cwts. c.i.f. English port guaranteed to contain 12¾% of nitrogen but in no case has it contained less than 13%. The above price in percentage nitrogen is equal to nitrate of soda at 15% and the latter should cost c.i.f. English port £9 2s. 6d.

* It is of interest to note that Schloesing has patented a clever method of making calcium nitrate, in which the nitrous gases are absorbed, while still hot, into briquettes made of quicklime. At first calcium nitrite is formed, but this, under the continuous action of air and nitrous gases, is converted into nitrate, so that the final product is calcium nitrate in a very handy form.

The prices of the various manures change from time to time, but assuming a unit value of 13s. 8d. per cent. of nitrogen all round the relative market prices should be :—

TABLE VIII.—RELATIVE MARKET PRICES OF MANURES.

	Nitrogen Content.	Price per ton.
	Per cent.	£ s. d.
Sulphate of Ammonia	19·75	13 10 0
Nitrate of Soda	15·00	10 5 0
Nitrate of Lime	12·75	8 15 0

SODIUM NITRITE AT NOTODDEN.

After passing through the granite towers the remainder of the nitrogen peroxide gas and the still unoxidised nitric oxide pass to two wooden towers 2 metres square and 10 metres high. These are filled with brickwork and over the bricks sodium hydroxide slowly trickles. This takes up what remains of the two gases as shown in equation (6).

As the resulting liquid contains some calcium nitrite, nitrate of soda, bicarbonate of soda, besides water, it is necessary to remove all these to get the pure sodium nitrite.

This is done by first evaporating off some of the water by means of steam from the steam boilers. The concentrated solution is then run into pans, in which the crystallisation of the nitrite takes place. The crystals are then separated by centrifugal means, and are conveyed by a screw transporter to a drying apparatus, where they are dried by a current of hot air. The finished product is then run into casks containing 6 cwts. each. This nitrite of soda is used as the raw material in the manufacture of various aniline dyes.

Ammonium nitrate, used for making blasting powders, is also made at Notodden from a by-product of English gas works.

It should be noted that all the processes of manufacture above mentioned are effected without the use of coal.

NOTODDEN POWER STATION.

The power station supplying the Notodden works obtains its water from lakes Tinnsjoen and Mosvand, the supply being seventy-five cubic metres of water per second, and the effective height of the fall 140 feet.

There are four Vorth turbines, each of ten thousand h.p., and each turbine fitted with two wheels. The number of revo-

lutions is 250 per minute. The three-phase alternators, by the Allmanna Svenska Electriska Aktiebolag, Vesteras, give 600 amperes per phase at 10,000 volts, 50 periods. The power is transmitted to Notodden by 24 wires.

The power station is erected in the bed of the river close in under the almost perpendicular western bank, and all the materials had to be lifted by cranes, about 150 feet up or down. The heavy portions of the machinery were carried over to the power station by a powerful aerial ropeway, stretched from the road on the east side of the river to the edge of the precipice. At the time it was built this power station was the largest in Europe.

The present production at Notodden is about 20,000 tons per annum of manure and 4,000 tons each of sodium nitrite and nitrate of ammonia.

Schonherr Tube Furnace.

This furnace was invented in 1905 by Dr. Schonherr working in conjunction with Mr. Hessberger and the Badische Anilin and Soda Fabrik of Ludwigshafen.

In this furnace an arc of great density is made to burn steadily inside a long iron tube, air being blown through the tube with a whirling motion so that every particle moves in a path like a screw.

Dr. Schonherr first tried blowing the air straight through, but he found that only a small proportion of the air went into the sphere of action of the arc and at the same time there was a difficulty in making the arc long enough and keeping it in the centre of the tube. The simple expedient of burning the arc in a whirling current of air at once solved the difficulty.

The Schonherr furnaces, as at work at Christiansand, are worked in sets of three, one to each phase, and each takes 600 h.p. at 4,200 volts. This is the pressure between any one phase and the neutral point which is earthed The furnace body is also at earth potential.

Fig. 4 shows a vertical section through the furnace and the connections to the alternating current supply. It will be noticed that one side of the alternating current supply is taken through an inductive resistance to the electrode E at the bottom of the furnace. This electrode consists of an iron rod which passes through a copper tube that has a water supply to keep it cool. The iron rod can be pushed upwards as it burns away to ferric oxide. Fresh rods are screwed in as required so that there is a continuous feed, but the wear is very slow. A new one every 2,000 working hours is sufficient, therefore the cost is only a few pence per k.w. year. The arc is struck by the iron rod Z, which can be moved inwards until it touches the top of electrode E. A peep-hole G enables the furnace attendant to see what is happening inside, and to give necessary adjustment to the electrode.

Air enters the tube tangentially by a number of holes which are near the electrode. This is a very important feature of the whole apparatus as it has been found that it is only by whirling the air through the tube that the arc will burn steadily in the centre.

A very important feature of the furnace construction is the water cooler at the top. It is inside here that the arc is made to end by suitably adjusting the sleeve S over the tangential orifices.

The arrows in Fig. [4 show the direction of the air and hot gases. It will be seen that air enters at the bottom, passes up the central annular space and down through the inner annular space.

As there are hot gases on each side of this space, the air is heated to about 500 deg. C. before it reaches the arc. After passing through the arc, where some of it is heated to about 3,000 deg. C., it reaches the water cooler and its temperature is suddenly reduced. Where the arc strikes to the tube there is a sudden mixing of the highly heated nitric oxide next to the arc, with the cooler air that is whirling past, and this fixes it permanently. The nitric oxide and air leave the top of the cooler at about 1,200 deg. C. and pass down the outer annular space, entering the gas flue, common to all the furnaces, at about 850 deg. C.

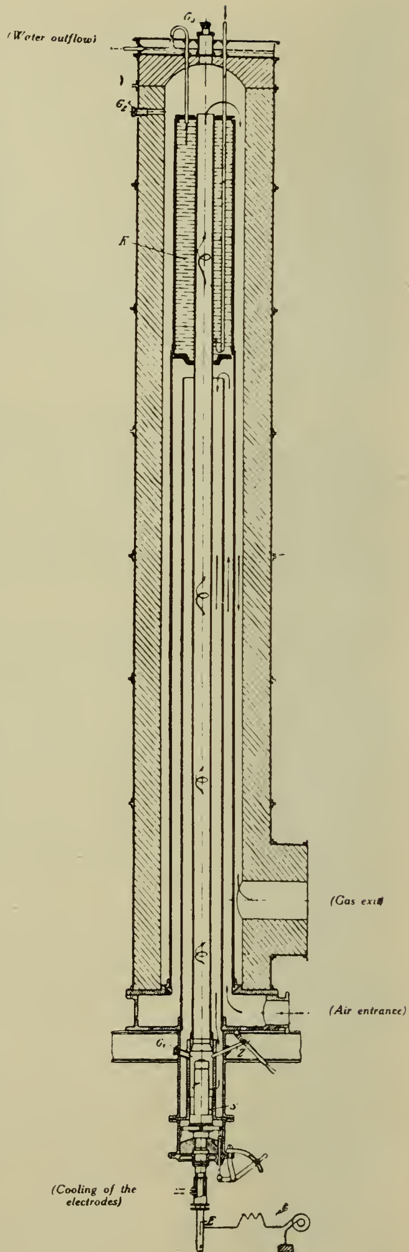


FIG. 4
THE SCHONHERR TUBE FURNACE.

Up to this point the gas has been colourless nitric oxide, but directly its temperature sinks below 600 deg. C. a further quantity of oxygen is taken up and the reddish-brown nitrogen peroxide gas begins to form. Complete conversion only takes place at 140 deg. C. and then only very slowly, so the gases are still further cooled by being taken through boilers, where they raise steam, and then to an oxidation tank. The gases remain in this tank for some time so as to change completely to nitrogen peroxide.

TABLE IX.—BALANCE SHEET OF THE HEAT ENERGY IN THE FURNACE.

40%	goes in heating water of the cooler.
17%	is lost in radiation from walls of furnace, pipes, etc.
30%	raises steam in the boilers.
10%	by cooling with water after passing the boiler.
3%	actually used for making the nitric oxide.

The air moves like a many-threaded screw, and this is done because it was found that when the air entered by one orifice the arc had a tendency to be wavy like a screw. Sleeve S regulates the openings of the orifices so that the amount of air can be regulated, and with it the length of the arc.

In the 600-h.p. furnace at Christiansand the arc is 16ft. long whilst in the 1,000-h.p. furnace it is 23ft. long. The latter requires about 40,000 cubic feet of air per hour.

After the arc is struck the whirling air immediately draws it out to a point where the gases have acquired such a temperature that they conduct. At this point the arc strikes across to the tube and it keeps turning slowly round in the direction of the whirling air. At the same time it moves slightly up and down as the air pressure varies and there is thus no pitting of the inside of the tube.

The inductive resistance is a most important adjunct of this as of every arc furnace. It effectively prevents another arc starting at the bottom of the tube and running up, because when the arc is burning steadily the voltage sinks to a point at which it cannot jump across from the electrode to the tube near it.

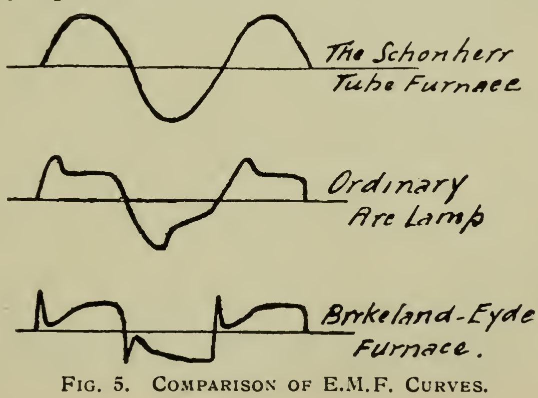


FIG. 5. COMPARISON OF E.M.F. CURVES.

One feature of this furnace is that the voltage current coincides very nearly to a sine wave as shown in Fig. 5. There is an entire absence of the peakiness of the Birkeland-Eyde furnace, or even of an ordinary arc lamp.

Interruptions only occur if for some reason or other there are sudden violent variations in the air supply, or if by reason of a short on the supply line there is a sudden drop in voltage.

Sodium Nitrite by the Badische Analin and Soda Fabrik.

This company entered into the business principally with the object of obtaining a cheap and constant supply of sodium nitrite for the production of azo dyes, etc. The plant at Christiansand is therefore employed solely in making nitrite. Previously sodium nitrite had been made by the reduction of Chili nitrate with lead, but this method of production has now practically ceased.

The temperature of the gases is not allowed to fall below 300 deg. C. and so the proportion of nitric oxide is kept about equal to the nitrogen peroxide. This mixture behaves as if it were nitrogen trioxide N_2O_3, and it is absorbed completely by being brought into contact with sodium hydroxide according to the following formula :—

$$NO + NO_2 + 2NaOH = H_2O + 2NaNO \text{ sodium nitrite.}$$

The nitrite made from the nitrogen of the air is so satisfactory and so cheap compared with the old methods, that now practically the whole supply of the world, valued at £160,000, is obtained from electrical furnace plants. It may be mentioned that it only takes about 12,000 h.p. to give the world's supply.

Calcium Nitrite.

It is interesting to note that the percentage of nitrogen in calcium nitrite is about 18% whereas in nitrate of lime it is 13%, and Chili nitrate contains 15%.

Von Lepel, Schloesing and Wagner have shown that nitrite is not injurious to plants as had been supposed, but that the nitrogen in it is of equal value to plant life, as is the nitrogen of nitrate. It may therefore become a rival of nitrate of lime as a manure.

Calcium nitrite can be made by bringing nitrogen peroxide and nitric oxide into contact with milk of lime.

Norwegian Saltpetre Combination.

Recently various interests in Norway and Germany have joined hands for the purpose of harnessing Norwegian water powers to manufacture nitrogen products on a large scale. The firms are :—

The Badische Anilin and Soda Fabrik, of Ludwigshafen.
Farbenfabriken vorm. Friedr. Bayer & Co., of Elberfeld.
Actiengesellschaft für Anilinfabrikation, of Berlin.
Norwegian Hydro-elektrische Stickstoffgesellschaft.

The Birkeland-Eyde and the Schonherr patents are therefore controlled by the same group, and the writer would not be surprised if those who are working the Frank and Caro process for making calcium cyanimide were not also taken into the combination.

The capitalisation of the combination may be worth mentioning. The Norwegian Electric Power Company has a capital of 16,000,000 Kronen = £889,000, simply for the purpose of harnessing Norwegian waterfalls. The Norwegian Saltpetre Manufacturing Company, with a capital of 18,000,000 Kronen = £1,000,000, is to build and run saltpetre factories in Norway. A third company dealing only with transport has a capital of 3,000,000 Kronen =£167,000.

Rjukan Power Station.

The Badische Anilin and Soda Fabrik is the controlling factor in the combination for granting licences, etc., outside Norway.

A waterfall which the combination is harnessing is Rjukan in Telemarken, and this is now in hand. It has a total fall of 560 metres with a regulated flow of 47 cubic metres per second. This will yield about 250,000 e.h.p. and the harnessing is being effected in two steps of 280 metres each. For the first fall ten turbines of 14,000 h.p. each have been built, and the alternators are being supplied by Brown, Boveri and Co. and the General Electric Co., Sweden.

The power station is about 3 miles from the saltpetre factory, and current will be transmitted by overhead aluminium cables which are being supplied by the South German Cable Works Co.

Both the Birkeland-Eyde and the Schonherr furnaces will be used, and the output of manure will be about 80,000 tons per annum.

The Badische Anilin and Soda Fabrik have also secured the water powers of Matre and Tyin in Western Norway, and it is proposed to make nitrogen products there as well, so that with these three projects nearly half a million horse-power will be available for this new industry, in Norway alone.

Besides the large works in Norway, the Badische Anilin and Soda Fabrik are also building a factory in the Alz in Bavaria. Water from the Alz is to be conducted into the Salzach and 50,000 e.h.p. will be developed.

The Pauling Furnace.

The Pauling furnace is being exploited by the Salpetersäure Industrie Gesellschaft at Gelsenkirchen, Austria, and at other places. This furnace is made on the lines of the well known horn break lightning arrester. As shown by Fig. 6 it consists of two hollow iron electrodes *a a* (cooled with water) arranged to form a vee which at the lowest point is about 4 cm. across. At this point there are two lighting knives which

can be approached to within a few millimetres, and are readily adjustable to take up wear by wheels *b b*. The arc strikes across and runs up the diverging electrodes by reason of the natural convection currents and the repelling action of its own magnetic field, but principally because of a blast of heated air from the nozzle immediately below.

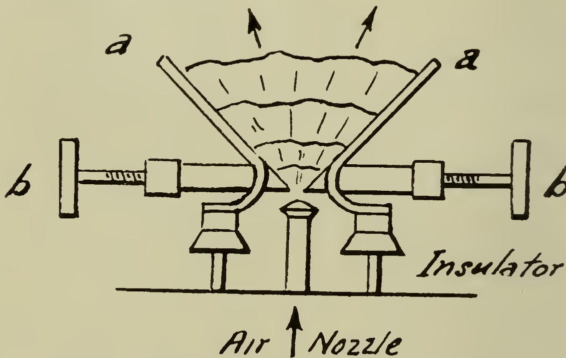


FIG. 6. PAULING HORN BREAK FURNACE.

The arc is caused to diverge so as to follow the shape of the electrodes, and it attains a length of about a yard before it goes out. At each half-period of the alternating current a fresh arc is formed so that the result is the equivalent to a triangular sheet of flame.

The furnace gases cool off rapidly as they mount upwards, and they are further helped by circulation air, which is introduced sideways into the upper portion of the flame at a lower speed than the main current. This has a kind of suction effect and draws out the flame sideways, thus increasing the cooling area.

The gases leave the furnace at about 700 to 800 deg. C. and contain $1\frac{1}{2}\%$ of nitric oxide.

At Gelsenkirchen there are 24 such furnaces each taking 400 kilowatts at 4,000 volts. Some larger furnaces of 1,500 h.p. are also at work on this system.

CONCLUSION.

It will be noticed that the process is unique in that the raw material, nitrogen, costs nothing, and it can be obtained in absolute purity in any part of the world. All that is wanted is cheap electric power. Although we can produce power as cheaply as the water-power plants of Norway, it is most important that works should be started in this country, because we are at present dependent on overseas supplies for the nitric acid with which to make explosives.

It should be mentioned that nitrogen is fixed by carbide of calcium to form a valuable manure. Calcium cyanimide or nitrolein and sulphate of ammonia and potassium cyanide are obtained from it.

F. G. BLOYD,

President of the Society of Engineers (Incorporated) for the year 1911.

Mr. F. G. Bloyd, whose portrait appears as a frontispiece, received his earlier training at the Crystal Palace School of Engineering under the late Mr. J. W. Wilson and the present Principal of the School, passing through both the mechanical and the civil engineering course. On leaving there he was articled as a pupil to the late Mr. Ralph H. Tweddell, of Delahay Street, Westminster, and subsequently continued in that office as an improver.

Mr. Tweddell was at that time actively engaged on the design of hydraulic machine tools for rivetting, punching, shearing and general shop and yard work, and plants from his designs were being installed at many of the Railway Locomotive Works, Shipyards, and British and Foreign Dockyards.

In 1886 Mr. Bloyd entered the Engineer's Office of the London, Chatham and Dover Railway at Victoria and served under the late Mr. William Mills, and afterwards under Mr. G. B. Roche, the chief engineers to that Company, up to the amalgamation of the Company with the South-Eastern Railway Company on January 1st, 1899, when he was transferred to the Office of Mr. P. C. Tempest, Engineer-in-Chief to the Managing Committee of the combined Railways, where he is still engaged.

Mr. Bloyd joined the old Society of Engineers in 1890, as an Associate, being transferred to the class of Members in 1901, and elected to the Council in 1906.

6th February, 1911.

ORDINARY MEETING.

MR. DIOGO A. SYMONS (PAST PRESIDENT)

IN THE CHAIR.

PRESENTATION OF PREMIUMS.

The Chairman presented the premiums awarded by the Council in respect of papers published in the JOURNAL during the year 1910, as follows :—

THE PRESIDENT'S GOLD MEDAL to Mr. W. C. Easdale for his paper on "Sewage Disposal Ideals."

THE WILLIAM CLARKE PREMIUM, value £5 5s. 0d. to Mr. S. M. Dodington for his paper on "Public Slaughter-houses."

THE BESSEMER PREMIUM, value £5 5s. 0d., to Mr. Chas. V. Biggs for his paper on "The Testing and Inspection of Engineering Materials and Machinery."

THE NURSEY PREMIUM, value £3 3s. 0d. to Mr. Henry C. Adams for his paper on "Current Professional Topics."

A SOCIETY'S PREMIUM, value £3 3s. 0d. to Mr. A. H. Allen for his paper on "Electricity from the Wind."

A SOCIETY'S PREMIUM, value £3 3s. 0d. to Mr. C. R. Enock for his paper on "Engineers and Empire Development."

Having presented the premiums, the Chairman expressed the thanks of the Society to the authors of other papers published during the last year, namely :—

MR. P. G. SCOTT for his paper on "Moulmein Waterworks."

MR. R. O. WYNNE-ROBERTS for his paper on "Up-to-date Roads."

MR. E. R. MATTHEWS for his paper on "Reinforced Concrete Retaining Walls."

MR. G. A. BECKS for his paper on "Some Engineering Troubles in Africa and their Solutions."

MR. REGINALD BROWN for his paper on "The Working of the Roads Development Act, 1909."

INDUCTION OF THE PRESIDENT.

The **Chairman** said that he had now completed his duties as President for the past year, and he had very much pleasure in introducing Mr. F. G. Bloyd, the President for 1911. It was quite

unnecessary to enumerate Mr. Bloyd's many good qualities, as he was well known to the members of the Society. He had much pleasure in vacating the Chair in Mr. Bloyd's favour.

Mr. Bloyd then assumed the Chair as President and was invested by Mr. Symons with the Presidential badge.

Mr. D. B. Butler said that it was now his pleasure to propose a vote of thanks to Mr. Diogo A. Symons for his services as President during the past year. The duty of proposing this vote of thanks always devolved on a Past President, for it was very rightly considered that only one who had served as President could appreciate the great amount of work which the occupancy of the Presidential Chair involved. Mr. Symons, as the members knew, occupied the chair during the year following the amalgamation, and although the amalgamation nominally took place the year before last, a very large amount of the work connected with it had devolved, during the past year, on Mr. Symons. If he (Mr. Butler) might be allowed to be reminiscent for a moment, he would like to compare Mr. Symons' year of office with his own, which was in 1904, the jubilee year of the Society. That year was also a year of very heavy work for the President, and that fact enabled him (Mr. Butler) to appreciate the work which Mr. Symons had done during the past year. When in due course, he (Mr. Butler) retired from the chair and introduced his successor, the then Secretary, their dear old friend the late Mr. Nursey, was good enough to make an unofficial speech supporting the usual vote of thanks, in which he gave some statistics as to the number of Presidential attendances at council meetings, committee meetings, and general meetings, during the year. The figures ran up into considerable numbers, and, though he could not quote them exactly, he could fully appreciate the amount of work which Mr. Symons had done. Only those who had passed the Presidential Chair knew the amount of work involved by the occupancy of it, which to a busy man was very considerable.

Mr. John Kennedy had much pleasure in seconding the motion. Mr. Symons, during his year of office, had done yeoman service for the Society, the value of which, he was sure, the members appreciated.

The vote of thanks was very heartily passed.

The retiring President, **Mr. Symons,** thanked the mover and seconder for the kind way in which the vote of thanks had been proposed, and the meeting for the cordial manner in which they had received it. As the first President of the Society after the amalgamation, he had tried to carry out his duties in a manner worthy of the position and in the interests and welfare of the Society,

and he was very glad to find that his efforts had been appreciated. The work of the past year had been particularly heavy, and many problems had been introduced which, he felt confident, would be brought to a successful issue during the coming year under the guidance of the new President.

Mr. Francis George Bloyd, the President for 1911, then delivered his

PRESIDENTIAL ADDRESS.

In assuming to-night the position of President of The Society of Engineers (Incorporated), I am compelled to preface my address by an expression of deep and sincere thanks, both to the Council of the Society for nominating me to the office, and to the members generally for kindly supporting the nomination, and electing me to hold the position for the coming year. By a somewhat happy coincidence my election occurs in the twenty-first year of my membership, a time when, in the ordinary course of life, a man reaches a distinct and important stage, and in taking this chair I similarly feel the dignity of the occasion, and can only trust that, with your cordial assistance, I shall be enabled to uphold the traditions of the position, and do all in my power to continue the work undertaken by my predecessors in the two constituent Societies.

My next duty is to congratulate the Society on the fact that, perhaps for the first time in its existence, either as an incorporated Society, or as the two old Societies which, by amalgamation, now form The Society of Engineers, arrangements have been made for the meetings to be held in a building worthy of the Society's standing, and the best thanks of the Society are to be extended to the President and Council of the Institution of Electrical Engineers for their kindness in allowing the use of this beautiful hall.

The incorporation of the new Society was formally completed on February 28th last.

The death of His Majesty King Edward VII. caused a wave of deep and sincere sorrow throughout the great Empire. The constant interest evinced by King Edward in the progress of science, and the important duties he assumed in connection with the inauguration of many great engineering works, are well known, and the Council fittingly expressed the heartfelt sympathy and assured loyalty of the Society in resolutions, which were forwarded to the Sovereign and the Queen Mother.

The Society have to record with regret the death of Sir John Aird, Bart., who joined the old Society of Engineers as far back as 1855, and whose career formed a striking example of successful business enterprise. Among the important works executed by

his firm were the Nile Dam, the Royal Albert and Tilbury Docks and several railways and extensive railway widenings.

Also of Mr. George E. Eachus, who was President of the Civil and Mechanical Engineers' Society for the sessions 1865-66 and 1866-67; and of Mr. Francis Brickwell, who joined the old Society of Engineers in 1867, and was made a Fellow of the Incorporated Society last October.

As regards the more domestic side of the Society's affairs during the past year, the Report issued by the Council covers the subject so thoroughly that any detailed references thereto would not appear necessary, and it is sufficient to note briefly that the total number who have signed on to the incorporated Society is equivalent to eighty-five per cent. of the membership of the two old Societies, a result which may be accepted as satisfactory, bearing in view that a certain proportion of resignations and cancellations inevitably follow an amalgamation.

The papers read at the meetings, or contributed to the Journal, embraced a wide series of subjects, and were well supported in discussion, while vacation visits were made to various works of engineering interest.

The arrangement by the Council, in conjunction with the Council of the Junior Institution of Engineers, for the delivery of a series of lectures on the Law relating to Engineering, marked a new and most useful feature of the Society's work, and it is to be hoped that the feature will be still further developed in future years.

The near completion of a scheme, now being considered by our Council, for the affiliation of Engineering Students' Societies to this Society will also mark another step in the progress of the Society's efforts to assist the younger members of the profession, and the results of the scheme will be awaited with much interest.

A closer perusal of the Report cannot fail to disclose the fact that the carrying to a successful issue of the amalgamation of the two old Societies, and the subsequent incorporation of the new Society, entailed considerable work to the Council and Officers. The work, however, has been gladly undertaken with the assurance that the members generally will express their due appreciation of the same by co-operating, as far as lies in their power, to assist the objects and aims of the Society, and an appeal for such co-operation will be made at the close of the evening.

Railway Construction and Equipment.

It has been the custom of the occupants of this chair to devote the technical portion of their addresses to a review of the work undertaken by the particular branch of the profession to which each has been attached, a custom that possesses distinct advan-

tages, inasmuch as it tends to bring forward in turn the many and varied phases of work that are comprised in the wide calling of an engineer.

Following this custom, it is proposed to present a few observations on railway construction and working, in so far as the subject is dealt with by the civil engineer, and although the remarks given may embrace only a small proportion of the points included in the very wide field of work which devolves on a railway engineer, it is hoped that the effort made will be judged lightly, owing to the difficulties met in endeavouring to treat so broad a subject within somewhat narrow limits.

Dealing with the railways of Great Britain and Ireland only, the total length of running track at the end of 1909 was 39,622 miles, while the length of sidings was 14,350 miles.

The total paid up capital was £1,314,400,000, while the gross receipts amounted to £120,170,000, and the total traffic receipts to £110,700,000, equivalent to £4,754 per mile. The total train mileage was 419,200,000 miles. Working expenses amounted to £75,040,000, leaving net receipts at £45,130,000, the proportion of working expenses to receipts being 62.4 per cent.

The average dividend on the ordinary capital was 3.15 per cent., and on the preferential capital 3.46 per cent.

Historical.

The inception of this vast network of railways may be traced to the formation of wagon roads at the collieries in the neighbourhood of Newcastle-on-Tyne, with a view to the better transport of coal from the pits to the staiths and wharves on the rivers. On the first opening of the pits the coal was conveyed in sacks or baskets on the backs of horses, after which ways paved with flagstones were made upon which carts and, later on, wagons were introduced.

About 1630 Beaumont improved these wagon-ways by laying down timber roads, which still further assisted haulage. These roads were about 6ft. in breadth, across them were laid oak sleepers, about 5in. square, and spaced from 2ft. to 3ft. apart. On these sleepers, longitudinal timbers, 6in. or 7in. wide and 5in. deep, were pegged down, at a distance of about 4ft. from one another.

This type of track required frequent repair, and eventually a second longitudinal timber was laid down on the top of the first main track timbers, and renewed as often as it wore away. This raising of the track-way allowed the space between the main timbers to be filled in with ashes or ballast, which assisted to preserve the cross sleepers from wear by the horses' feet. Similar ways were laid down at the collieries in Cumberland, and also in Wales and Scotland. In course of time many of them

developed into works of some magnitude, the ground being levelled to secure better gradients.

The next improvement to be effected was the lining of the upper surface of the longitudinal timbers with iron plates, and about 1738 cast-iron rails are said to have been introduced at Whitehaven, but it was not until a later date that a serious attempt to make use of an iron track-way was accomplished at the Coalbrookdale Ironworks, where, in 1767, a plate road, having flanges or vertical ledges to prevent the wheels slipping off, was laid down. Cast-iron wheels, turned in a lathe, were now used, and led to considerable economy in traction.

In 1776 a cast-iron plate-way, spiked to timber sleepers, was laid down at Sheffield, to serve a colliery belonging to the Duke of Norfolk, but was bitterly objected to by the workmen there, who resented the introduction of such a labour-saving device, and led to the way and coal staith being destroyed.

In connection with the subsequent improvement of the track ways, and the introduction of the grooved rail and flanged wheel, the names of James Outram and William Jessop occupy an important position, and it is to these two earnest and gifted pioneers that the credit of the first railways, as the tracks were now termed, is to be ascribed.

The first company to be incorporated by an Act of Parliament was the Surrey Iron Railway Company, whose Act was passed in 1801 to make a railway from Wandsworth to Croydon, with a branch to Carshalton. This line had a double set of rails throughout, was nine miles in length, and cost £60,000.

In 1803 another company was incorporated, under the title of the Croydon, Merstham and Godstone Iron Railway Company, to "make and maintain a railway passable for waggons and other carriages from or near a place called Pitlake Meadow in the town of Croydon, to or near a place called Reigate, and also a collateral branch from the said railway at Merstham to a place called Godstone." This line was not constructed beyond Merstham, to which point it was opened in 1805.

In regard to this line it is interesting to note that, on the promotion of the existing railway to Brighton, in 1837, the company, to whom powers to make that railway were finally conceded, were compelled to buy up the old iron railway, and, as forming a link with the past, it may be mentioned that some of the small stone sleepers laid on this old line are in use in Croydon as kerbstones to this day. Horse or mule traction only was employed on these and the other earlier lines.

In the matter of the invention and first application of steam as a means of power, it is not possible to refer here to the many steps through which the idea passed from the days of Hero of Alexandria to the efforts of Baptista Porta, Solomon de Caus, Branҫa, the Marquis of Worcester, Thomas Savery, Newcomen,

and others, until the genius of James Watt evolved the steam engine as a practicable and serviceable machine.

As regards the use of steam as a motive power, a patent was taken out in 1802 by Richard Trevithick for a locomotive carriage, which was probably the first attempt to adopt the power on a rail road. Two years later Trevithick obtained a further patent in conformity to which an engine was built that ran a trial trip at Merthyr Tydfil, on February 22nd, 1804, on the tramroad from the Penydarren Ironworks to the Glamorganshire Canal, a distance of nine miles, drawing 10 tons of bar iron and some 70 people at a speed of 5 miles per hour.

In 1814 George Stephenson placed his first locomotive on the Killingworth Railway, when a load of 30 tons was dragged up an ascent of 1 in 450, but he, too, experienced many difficulties in inspiring confidence in the practicability of his ideas.

The preamble of the Act passed in 1821 for the construction of the Stockton and Darlington Railway, set forth that "the making and maintaining of a railway or tramroad for the passage of waggons and other carriages will be of great public utility by facilitating the conveyance of coal, iron, lime, corn, and other commodities," but contained no mention of the use of locomotives thereon.

It is now, however, a matter of history how, on the opening of the railway, on September 27th, 1825, the locomotive designed and driven by Stephenson started off on its journey with a load of 90 tons, and attained a speed of 12 miles an hour, and the subsequent opening of the Liverpool and Manchester line, on September 15th, 1830, completed the foundation of the English railway system.

Legislation.

Before turning to more recent practice in railway engineering it may prove expedient to consider a few of the General Acts which have been passed to control the construction and working of railways, Parliament having decided at a comparatively early date that special legislation was needed to meet the case.

One of the earliest of these statutes was the Act of 1838 making provision for the carriage of mails, which was followed by three Acts, passed in 1840, 1842, and 1844, dealing with the general regulation of railways. The year 1845, however, marked a more important step in railway legislation, three far-reaching and comprehensive measures being passed in the Companies Clauses Act, the Lands Clauses Act, and the Railway Clauses Consolidation Act, the several provisions of which, in so far as they are applicable and have not been amended, being incorporated in all subsequent Acts of Parliament authorising undertakings of a public nature.

The first of these measures covers the incorporation of companies and their financial obligations, the appointment and powers of directors, and may be termed the "Business Charter." The second Act, as its title implies, deals exhaustively with the acquisition of land and property for public works, over which compulsory powers have been obtained, either by agreement or by notice to treat, the settlement of disputed claims by arbitration or by jury, and other points affecting the owners, occupiers, or tenants of the lands, thus forming the "Land Charter." The third Act, which may be termed the "Works Charter," varies somewhat in its interpretation from the first two, inasmuch as it applies solely to the construction of railways, and provides for deviations in line and level from the original plans, the formation of tunnels, embankments, bridges, roads, ways, passages, drains, arches, cuttings, and fences, and the subsequent alteration, repair or discontinuance of such works, and the alteration of gas and water pipes. Regulations are also contained therein governing the taking of land for temporary purposes, and for the making of additional stations, yards, and wharves, or the formation of convenient roads or ways to the railway. Special provisions are made for level crossings over public roads, for the width and headway of the several descriptions of bridges, and for accommodation works. The working of mines under or near railways is dealt with, and the general working of the undertaking provided for. These three Acts were amended in certain respects and their provisions enlarged by three similar measures passed in 1860 and 1863.

The Act passed in 1846 for regulating the gauge of railways was an important measure, as it definitely established the narrow gauge of 4ft. 8½in. as the standard in Great Britain and the 5ft. 3in. gauge in Ireland.

Several further Acts of a controlling nature were passed during the following years, but, with the exception of the Railways Construction Facilities Act, 1864, the attitude of the State towards railway promotion continued to be restrictive rather than co-operative. This latter Act, however, sounded the first note of assistance, and provided that, if the promoters of a railway were able to secure the united consent of the landowners affected by the scheme for the purchase of the required land, then the Board of Trade might issue a certificate authorising the construction of the line, which certificate would, with the consent of Parliament, operate as a Special Act. The advantage conferred by this Act was unfortunately considerably curtailed by the passing of the Railways (Powers and Construction) Acts, 1864, Amendment Act 1870, which re-introduced the risk of heavy Parliamentary expenses being incurred, with the result that only a very small record exists of railways being made thereunder.

In 1896 the Light Railway Act was passed with a view to facilitating the construction and working of such lines in Great Britain, an important feature of this statute being that the Treasury (within certain limits) or Local Authorities, were empowered to grant financial aid in cases where railway development could not otherwise be secured.

When introducing this measure in the House of Commons, the late Mr. C. T. Ritchie tersely remarked : " The main difficulties hitherto had been, first, the unwillingness of Parliament to authorise the compulsory acquisition of land otherwise than by a scheme directly approved by Parliament itself, and the consequent cost of obtaining approval. The second had been the expense of the requirements for the public safety enforced by the Board of Trade."

The passing of this Act and the appointment of the Light Railway Commission was regarded as a helpful step towards securing the provision of railway facilities in outlying or sparsely populated districts, and although the results which have accrued may not be thought to come up to the first expectations formed, it must, in fairness, be admitted that the failure is not to be altogether ascribed to the inability of the Act, as an item of legislation, to authorise the measures that are undoubtedly needed, but rather to outside circumstances which tend to restrict the construction of lines on a scale and at a cost that would lead to a reasonable hope of profitable working.

The latest report of the Light Railway Commissioners states that the total number and classification of lines approved by them under the Act up to the end of 1909 was :—

Class.	Number.	Mileage.	Engineer's Estimate.
Class A	144	1,377	8,518,931
,, B	145	639	6,083,195
,, N	9	54½	553,054
Amending	85	—	167,148
Total ...	383	2,070½	15,322,328

But when the question of construction is touched on, the Commissioners are forced to admit the need for the revision of the policy of the Act in the following words, which will be carefully weighed by all who have studied the question of outlying travelling facilities :—

" Upon examination of the lists we find a large number of light railways, the need for which has been established at public

inquiries held by us, and for which Orders have been confirmed by the Board of Trade, but of which the construction has not (so far as the Commission is informed) been proceeded with up to the present date, and as to a large proportion of which the powers have already lapsed.

"Whereas 46 light railways, with a length of 375 miles in Class A (lines on lands acquired, mostly steam motive power) and 54 light railways with a length of 326 miles in Class B (lines on public roads, mostly electrical motive power) have been constructed, the powers given by the Orders have not been carried into effect in the case of 61 schemes, with a length of 765 miles, in Class A, and of 35 schemes, with a length of 210 miles, in Class B; these powers have finally lapsed for 33 schemes (421 miles) in Class A, and for 24 schemes (138 miles) in Class B.

"It may be observed that the chief difficulty in proceeding with schemes already authorised has been in finance, while the failures enumerated above have had the effect of deterring other proposals. In relation to lines of Class B, experience has shown that the absence of any provision under the Act of 1896 for submitting to Parliament proposals which are required to be so submitted in accordance with the Act, renders the procedure unavailing, and practically unavailable, in many cases.

"To what extent, and in what way, the policy of the Act should be revised must present a difficult problem; but we may perhaps draw attention to the marked success of the system adopted in Belgium under which a total length of more than 2,000 miles of light railways, constructed with moneys raised on national credit, is already being worked without loss to the State, while a further length of some 2,000 miles has been projected."

On many hands it is thought that finance alone is responsible for this restriction in construction, and, as is the case in all commercial ventures, finance does often form a very important element in the question; but it cannot be seriously urged that the conditions, which made Government aid imperative in the case of the construction of similar lines in Ireland, prevail to anything like the same extent in England or Wales, and it is doubtful if any enlargement of the Government subsidy provisions would entirely effect the desired improvement.

With a view to discovering a solution of the question it is submitted that the initial cost per mile, at which a steam-worked line is capable of being constructed and equipped, is too high, under present conditions, to ensure an adequate return in many districts, where facilities are most needed, and that until the regulations can be relaxed to meet the special circumstances that often obtain, and the more cordial assistance, not merely the sympathy, of local authorities and landowners can be enlisted,

there will be but small inducement to capitalists to find money for the schemes.

A further point for consideration is, as to whether the great advance made during recent years in the construction and working of mechanically propelled road vehicles has not materially altered the situation by providing more economical and remunerative first means of communication between outlying districts than could possibly be secured by a light railway.

This may mean that one branch of mechanical transport is temporarily supplanting another branch, but if the former is regarded more in the light of a forerunner rather than as an actual supplanter of the latter, which will probably follow at a later date when the increasing traffic demands a more efficient service than could be conveniently given by road transport, another link may be discovered in the chain of solution.

Construction and Equipment.

Having reviewed, although too briefly, the earlier stages in railway work, and touched on the legislation relating thereto, the natural sequence would be the consideration of the more modern practice in construction and equipment, the latter head embracing permanent way and signalling.

With respect to construction, it is not proposed to attempt to present any complete résumé on the subject, but only to refer to one or two points which more nearly concern the maintenance engineer, whose experience on the upkeep of the works can be applied, with distinct advantage, to the planning and execution of new schemes.

Perhaps one of the most unsatisfactory items of expense which a maintenance engineer has often to incur, is the cost of dealing with earthwork slips, unsatisfactory inasmuch as the money expended on the work is entirely unproductive, and also because the difficulty is frequently a recurring one, despite the fact that every effort may have been made to meet the evil.

When planning the initial construction of a railway it is not always possible accurately to gauge the character of the whole of the subsoil, and although borings may have been made at spots where any doubtful conditions have been anticipated, the preliminary earthwork calculations must to some extent be based on assumption.

The ideal arrangement in this respect would be to secure as exact a balance as possible between the cuttings and embankments, provided the leads so entailed were not too great ; but in cases of cuttings where clay or alluvial soil of a treacherous nature is met with, it is suggested that it is not always true economy to endeavour to obtain the balance by carrying the whole of the excavation into an adjoining bank, and that the better way,

unless land is highly priced, would be to run a good proportion of the unsuitable material to spoil, and obtain the stuff required to complete the bank from side cutting in a more favourable locality.

Much good can be done by attending to the manner in which banks are formed, and, although opinions may differ as regards the relative values of side tipping and end tipping, it will generally be admitted that the best results can be obtained by restricting the height of the leads, and placing the tip roads so that the full width is dealt with as the work proceeds.

If a bank has to be tipped on a sloping formation, it is sometimes thought desirable to level the site with a view to obviating risk of side slipping, but in such cases care should be taken to prevent any accumulation of water in the benching on the higher side at the toe of the new bank, an operation which may be easily attended to before the bank has been formed, but which it is difficult to effect in after years when the bank has become saturated and shows signs of failure.

Similarly, in the case of cuttings through sidelong ground, it is imperative, if the future stability of the slope is to be assured, that the drainage from the adjoining land should be dealt with as efficiently as possible. Intercepting drains may be laid to collect all water discharged from existing land drains, but unless thorough collection and a satisfactory outfall can be guaranteed, it would appear preferable to construct at once an open channel down the side of the slope where any well defined flow of water occurs, and lead the same into the formation drain running through the cutting.

An open-top ditch along the high side of a cutting had better be avoided unless a good longitudinal fall can be given for its entire length, as any accumulation of water in the ditch inevitably leads to the ground at the top of the slope becoming saturated and liable to slip.

Embankments formed of clay frequently stand well at first, and encourage the hope that careful attention to their formation has removed all risk of trouble occurring, but any great variation of climatic conditions often entirely changes the aspect of things. The ordinary London clay contains from 10 per cent. to 12 per cent. of water, and if the material can be retained in its natural state but little fear of instability need be felt. When, however, clay has been tipped into a bank there is a risk that, during periods of excessive drought, or in consequence of a too elaborate drainage system, the normal percentage of water in it may be much reduced, thus leading to shrinkage and the formation of cracks. These give ready access to water on the resumption of rainfall, and lead to slippery surfaces being formed which set up movements in the bank. To guard against this, and also to prevent rain or melting snow from percolating to any undesired

extent, it would appear advisable to cover the slopes with a specially good layer of soil, carefully spread and levelled, and pay extra attention to the sowing of the same.

It would seem almost superfluous to refer to the necessity of thorough attention to formation drainage, but in cuttings through clay or alluvial soil the expenditure on a complete drainage system at the outset will repay itself many times over, especially if the situation is bravely faced and the natural soil excavated to a sufficient depth to admit of the road bed being formed on a good foundation of non-water bearing material. On shale formations, the spreading of a good layer of ashes or clinker before the permanent way is laid out and ballasted will save considerable trouble in the future by preventing the material from working up and choking the ballast and side drainage.

The spanning of water channels also needs thought, and bridges will not be planned before careful investigation has been made into the varying conditions of their flow and volume in flood. Where a channel of moderate size cuts the course of a projected railway on the skew, it is not always economy to build a right-angle bridge with a view to saving money on the first cost of the structure, unless definite assurance is obtained that the flow is permanently regular, as such a structure forms a serious obstruction should floods occur, and even under normal conditions a scouring of the channel bed in the vicinity of the bridge will ensue.

The better plan, although slightly more expensive at the outset, due to the increased length of the abutments, would be to build the bridge over the natural course of the channel, making the span of sufficient width to accommodate the full flood flow, or, if such a span necessitated too heavy a superstructure a main span of smaller size might be provided with additional openings on either side to carry off floods. In bridges of this description it is suggested that the up-stream ends of the abutments or piers should be taken down deeper than the remainder of the work, and that the bed of all channels of moderate size should be inverted, as such precautions add considerably to the stability of the structures, and the extra cost is trifling when compared with that incurred in the event of a "wash-out."

In the case of an embankment being formed over land where the various holdings are divided by dykes or streams flowing in a uniform direction, it has often been deemed the cheaper plan to divert the course of one or more of such streams and carry the combined flow under the bank through a single culvert. It is suggested, however, that such an action has been the direct cause of serious slips through water continuing to pass along the original course of the stream and saturating the bed of the bank, and that the better and really more economical scheme would have been to have constructed a separate culvert for each water-

course in the first instance. The water question generally cannot be too carefully considered, and a little extra expenditure thereon in the first place will prove a most satisfactory investment in after years.

The character of the brickwork in tunnels, bridges, retaining walls and other works needs more attention than it sometimes receives. If locally made bricks be employed, care should be taken that a really good hard sound article is procured, and if a satisfactory class is not obtainable a suitable brick should be purchased elsewhere for all face work which has to stand exposed weather. Certain classes of red bricks, made from sandy clay, are especially unsatisfactory and entail early expense in repairs. Patching brickwork, in addition to its cost and unsightliness, does not in any way augment the strength of the structure, as it is not possible to restore the full value of a thoroughly good bond in the work. For tunnels, nothing but a good class of brindle bricks should be used and, if the extra expense can be borne, it would pay in the end to utilize the same brick for all exterior work in bridges and walls.

Recent improvements in the design of reinforced concrete enables that type of construction to be adopted to considerable advantage in bridges carrying roads or footpaths over a railway, but if girder work is employed, the under surface of all steel or ironwork should be thoroughly encased to avoid corrosion by steam and smoke, or, if encasing be considered detrimental (and the practice is open to objection inasmuch as it precludes a thorough examination of the girder work), an extra rust plate should be provided to allow for loss of strength by corrosion.

In girder bridges carrying railways over public roads, especially where such occur in an embankment formed of clay or other heavy material, trouble is frequently experienced through cracks showing down the face of the abutments, and although the safety of the bridge may not be actually affected, yet the appearance of such defects raises adverse comment, and necessitates repairs being undertaken.

Careful observation will show that the cracks usually start on either side of the centre of the abutments, a short distance below the girder bed stones, and extend downwards, more or less vertically, to the ground line, and merely to cut out and reinstate the outer skin of brickwork is neither a wise nor an economical course to follow, as, in the majority of cases, the cracks reappear, thus showing that the root of the disturbance has not been reached.

If the matter be thoroughly investigated by sinking trial holes down behind the abutments, it will often be found that the internal brickwork, or, where the abutments are pocketed, the brickwork of the divisional walls of the pockets, has been loosely laid, and the pockets themselves filled with unsatisfactory

material, although concrete filling may have been specified on the drawings; and to effect a complete cure the defects should be carefully remedied, and the trial holes filled in with concrete to form counterforts. The face brickwork may then be repaired with a reasonable hope of the work standing satisfactorily.

Too often, also, in such cases, the adjoining embankment was tipped close up to the site of the bridge before the bridge itself was erected, the toe of the tipping reaching almost to the line of the back of the abutments, thus forming a slope on either side of the bridge, which probably became a hard, smooth, surface before the bank was finally completed.

The residue of the tipping would naturally have but very little cohesion on these slopes, especially when surface water found its way down thereto, and would press forward, thus subjecting the abutments and also the wing walls, in which similar defects often occur, to an undue strain in after years, which might have been obviated if the slopes had been properly benched and the filling carried out with dry material, and in shallow layers, as the abutments were taken up.

The moral of the foregoing remarks would appear to be that increased attention is necessary during the initial stages of the work, the ideal to be aimed at being for the constructional engineer to regard himself in all respects as identical with the maintenance engineer, upon whom would devolve the subsequent upkeep of the work.

Stations.

The location, design and construction of stations deserves a little thought, and on the first of these heads the sites will be selected so as to secure the best traffic results. A good access to a station is most desirable and is, perhaps, best obtained by choosing a site adjoining a main road. Unless special reasons exist to the contrary, it would not appear necessary to attempt more effectually to serve a small town or a village by erecting a station on a central site therein, where land and compensation costs would be heavy, it being suggested that all reasonable requirements are met by selecting a suitable position outside but in fair proximity to the town, where more ample space can be procured to accommodate all descriptions of traffic. Moreover, as building operations invariably follow the erection of a station, a better opportunity is thus afforded traders of putting up premises close to the railway, to the common advantage of both parties and, incidentally, to the benefit of the town itself.

In the matter of the area of the land to be purchased, and the extent to which the station works should be first carried, the engineer may possibly be bound by finance, but, if such conditions do prevail, it would appear the better policy to be liberal as regards the land, the price of which will inevitably

increase in the near future, and at all costs to free the site at once from any public rights of way that may exist thereover. With respect to the works, these may sometimes be reduced in the first instance to the minimum expected to be required by the commencing traffic, and if each portion is planned so that it forms part of a comprehensive whole, and does not entail demolishment to make room for extensions, the increase in traffic can be met as it occurs without difficulty or the unprofitable expenditure of capital. To this end, it is advisable to have a standard design for stations, in which the several stages of extension are made practicable without much structural alteration to the portions already provided.

The main station building should be placed on the side of the line from which the greater portion of the traffic is likely to arise, thus reducing crossing over as far as possible, and at the smaller stations, the roofing over the adjoining platform, and also over the entrance to the station, may be conveniently provided by extending the main roof members as cantilevers both back and front of the building, thus obviating the erection of columns along the most used length of the platform.

It will generally be found preferable, as well as conducive to the health of the staff, to erect a separate house for the official in charge of the station, rather than to provide apartments in the station building itself.

A subway to connect the platforms entails but little extra expense in the first place and is much cheaper in future maintenance than an overhead footbridge. Moreover, no obstruction of signals is caused. The steps to subways should not be allowed to encroach on the clear width of the platforms.

The signal box and the lamp or oil store should be kept well removed from the main building, the latter being placed handy to one of the platforms but apart from other structures.

If economy must be practised, the buildings may be erected in timber instead of in brickwork, the proportional costs being about 5 and 9, but the maintenance expenses for the former type of work will be heavier.

The station drainage should be led away at the back of the building as far as possible, the laying of any soil drains along the permanent way being specially avoided, on account of the liability of the soundness of the drains to be disturbed by vibration, and the difficulty of providing proper inspection pits, or of repairing the drains. If cesspools have to be used it saves much trouble if all surface or roof water is dealt with separately and led away to a convenient outlet.

Many other items of detail arise upon which it is not possible to touch, but in the construction of platforms it is recommended that solid walls and coping should be adopted in lieu of timber work, which is costly to maintain. On made ground, however,

timber construction may perforce have to be used, unless heavy expense in foundations can be faced, but in such cases considerable trouble often ensues in keeping the work up to line and level, and timber should be avoided as far as the means at hand will permit.

Should an overbridge occur at the site of a station, a good plan is to erect the station buildings over the railway adjoining the bridge with access thereto, and provide a single island platform on the lower level of sufficient width to accommodate both lines of traffic. It may be argued that such a step possesses a drawback inasmuch as it entails a slewing of the lines of rails at either end, but this may be accomplished on easy curves which will not affect fast running, and the merit of the scheme is that only one platform is required, which obviates any duplication of waiting rooms and offices, thus reducing lighting and staff expenses, as well as ensuring a more complete control over the access to and from the station.

The laying out of goods yards allows of more economy being effected at the outset, as the accommodation can be more easily allowed to follow the expansion of traffic. In this work, however, great assistance will be felt in the future if the earlier sidings and works are planned as parts of the completed yard. It is advisable to arrange that rail access is given to the various parts of the yard, such as coal wharves, cattle pens, loading docks and the general goods sidings without unduly disturbing trucks standing on other lines, so as to admit of quick manipulation of any one branch of traffic without detriment to the remainder.

Length of site is perhaps of more importance than width, as the former allows of good parallel sidings being laid in and also leaves room for a draw-ahead road which obviates the user of the running lines during marshalling operations, while, as regards the levels of the site, should other circumstances be favourable, considerable assistance is afforded to shunting if the sidings be laid on a gradient falling slightly towards the buffer stops.

A goods shed of small size will probably suffice in the first instance, but the building should be placed in a position which leaves space for its future enlargement being effected without alterations to the sidings, the office and weighbridge being erected at the end which is not likely to be disturbed. A standard design of shed, planned in bays of a fixed length permits of extensions being provided with proper regard to cartage openings and platform accommodation, and enables a price per bay to be established for such work.

Before concluding the section on stations, a few lines may be devoted to water supply, which, in outlying districts where no main supply is available, is a point which often presents some little trouble.

Apart from the water needed for the station, it may be thought desirable also to provide a supply for running purposes, and a good supply under this latter head on a branch line will often allow a lighter type of locomotive to be made use of, in addition to assisting traffic arrangements by enabling the engine to carry out extended working without returning light to the junction or terminal station for watering purposes only.

Information as to the quantity and quality of the water to be obtained at any selected spot is generally procurable from an investigation of the wells in the immediate neghbourhood, but a careful analysis is recommended, especially if trial borings are made, in order to ensure that the supply is suitable for boiler use. A locomotive supply demands adequate tank storage at a height of from fifteen to twenty feet above rail level, and it is here proposed to bring forward the question of the most economical manner of raising the water.

In former days a manual worked pump, or a steam pumping plant, was generally used. More recently oil engines have been employed, but all these methods entail varying expense for labour, and attention is directed to the point as to whether wind power might not be made more use of for pumping duties.

The trials carried out by the Royal Agricultural Society over a period of two months showed that a four horse-power windmill pump was capable of raising nearly fifteen hundred gallons per day of ten hours to a height of two hundred feet with a wind velocity of six miles per hour, or a quantity of ten thousand gallons with a twenty-four m.p.h. wind. The Board of Agriculture have also adopted a comparative standard of the cost of wind power, which is, that a twelve-foot diam. windmill of the best construction will develop approximately one horse-power gross with a wind velocity of fifteen miles per hour.

A practical example of the application of this type of power for pumping purposes in connection with a locomotive supply on an outlying branch line may be cited, the plant having now been in use some eighteen months, during which time an ample supply has been maintained at a purely nominal expense for periodical examination and oiling.

The rest water level in the well is thirty-one feet below ground line, and a tank holding ten thousand gallons is placed at a height of twenty-one feet above rail level.

A twelve-foot diameter annular sail wind mill, fixed at a height of sixteen feet above ground line, was provided—the specification stipulating that the mill should be capable of raising seven thousand gallons of water per day of twenty-four hours, to a total height of one hundred feet, with a wind velocity of ten miles per hour. On the initial trial of the mill, over eight thousand gallons were raised in twelve hours, the conditions varying from a gale to a strong wind. On a very calm

day the mill was found to deliver only seven hundred gallons during a twelve-hours test, but the tank storage has always been sufficient for every requirement.

Under present working arrangements the supply is not drawn upon much beyond one-half of its full capacity, but even under these circumstances the cost of pumping the actual quantity of water used, after allowing an ample sum for depreciation does not exceed threepence per thousand gallons.

Permanent Way.

The earlier efforts of railway engineers to design a form of permanent way which would prove as firm and lasting as possible were not attended with either satisfactory or economical results, and it was speedily discovered that a too rigid road caused great damage to rolling stock, and also to the lighter parts of the road itself. For these reasons, the stone block sleepers, which at the outset were extensively laid down at a considerable expense, were abandoned in favour of timber sleepers, and the piled road, designed by Brunel for the first permanent way of the Great Western Railway, met with a similar fate.

The use of timber sleepers was not, however, altogether regarded as an economical procedure, and various types of "iron road" were introduced and laid down on different railways. At a much later date, efforts were made to design a steel trough road, and, more recently, exhaustive trials have been carried out of various forms of reinforced concrete sleepers.

Apart from these efforts towards improvement, the main features of the ordinary chaired road, which was finally adopted as the most satisfactory type of permanent way, have really altered but very little during the past forty or fifty years, a fact which is in many ways somewhat remarkable when it is remembered what drastic changes have been made in other branches of equipment.

Improvements in design, and in the processes of manufacture of the several component parts, have, of course, followed, and a general strengthening has been effected to meet increasing weights and speeds, but the general form of track remains, and it would, perhaps, be difficult to suggest any material betterment on that head.

In the matter of detailed design, as distinguished from general type, continuous investigation is being made into several points with a view to ensuring thorough smoothness in travelling and economy in the life of the materials; the first-named being, perhaps, most desired, although the second is also an important element, and as regards these points perhaps the further improvement of the rail joint is the subject which is more nearly engaging attention at the present time.

The fact that divergence of opinion exists, and that different

types of joints are in use, would seem to infer that finality in this question has not yet been reached. In all structures a joint is naturally the weakest spot, and rail joints form no exception to the rule, on the other hand, they rather emphasize it.

Numerous types of supported joints have been introduced, but the suspended type is now most in use, the actual suspension length being minimized as far as possible by extending the chair seat on either side towards the joint, and the road generally strengthened at the spot by putting in joint timbers of a larger size than the intermediate sleepers. A closer spacing of the adjoining sleepers also assists the situation, while the increased length of rails now being laid down materially reduces the number of joints.

Perhaps one of the most satisfactory forms of joint, from a purely support point of view, is the bridged joint in use on the flat-bottom section of rail on the American lines, and although this type of joint does not lend itself so readily to a chaired road, yet a modification of the idea will probably form the future standard joint on railways generally.

The improvements effected during recent years in the chemical composition of rail steel, and the introduction of special descriptions of hardened steel for point and crossing work, have all tended to prolong the life of the road, and thus assist the work of upkeep by obviating the necessity of such frequent renewal.

From the economist's point of view, the subject which will probably call for closer investigation at no distant date is that of the supply of suitable timber for sleepers, the consumption of which has increased with the growth of ıailways, and despite the careful attention given to the various preservative measures employed to delay decay as far as possible, the demand for the material must inevitably exceed the supply unless steps be taken to more adequately provide for the same.

The introduction of the harder woods of Australia and other countries has doubtless temporarily relieved the drain on the softer kinds of timber, and the experiments now being made with reinforced and other forms of built-up sleepers will be watched with close interest.

Following on the efforts of the designer, the chemist and the manufacturer, to supply as perfect and sound a type of permanent way as possible, the closer attention of the maintenance engineer to the general upkeep of the road has been of almost equal value in securing the high standard of excellence which now obtains, and the importance of the latter duties cannot be too strongly stated if thoroughly satisfactory results are to be assured. The inherent advantages of the best possible type of road would be greatly nullified but for the systematic care of the maintenance staff, and the practical recognition of this fact is likely to do far more good than many of the

purely theoretical improvements in the design of the road which are constantly being put forward.

Signalling.

In few other branches of equipment has a greater advance been made than in signalling, the reasons for this advance being the increasing call for expeditious movements of traffic while preserving absolute safety in working.

Between the original "time" signalling methods and the subsequent application of "space" signalling, followed by the grouping of levers and the introduction of interlocking and other precautionary measures, the improvements made in the mechanical branch of the work have been many and of great import, while the adaptation of electricity as a control on the mechanical working has done much to complete the march of progress, with the result that although British railways are in some quarters reproached as being the most expensively signalled lines in existence, yet they also hold the more satisfactory position of being the safest lines of transport in the world.

Many items of interest present themselves in tracing the gradual evolution of signalling, but as it is probable that a paper on the subject may be presented to the Society during the year it is now only purposed to invite attention to one or two points in general practice.

In the first place it is suggested that the recently introduced plan of multiple route signalling in place of the former system of having a separate signal to govern each movement within a section, is open to objections which are not altogether balanced by the saving in lever maintenance which the plan may effect. In the multiple plan, only one signal may be provided to govern movements in two, three or even four distinct directions, the signal thus being permissive only and not directive as to the route to be followed, and although the movement may be carried out under the control of a shunter the working can hardly be regarded as so satisfactory as the former system in which a visible signal defined the exact route at the start and further indications confirmed the correctness of the movement at each point of divergence, thus removing all ground for uncertainty or doubt of the signalman's intentions.

Any unnecessary multiplication of shunting signals is not advocated, but care should be exercised in removing signals that assist a driver in personally determining the safety of a movement he may be carrying out, even though the working may be done under a shunter's directions.

The second point has reference to the provision of "outer home" signals at junctions or other spots where it may be thought expedient to give a driver a more complete intimation of the state of the route than is afforded by a single distant and stop

signal, such as at an intermediate box on a long falling gradient or at a station placed at the foot of such a gradient where curvature of the railway prevents a good view ahead being obtained. In such cases the provision of an "outer stop" signal in a position rather over a full train's length from the stop signal proper, which then becomes an "inner stop," gives timely warning to a driver and removes all risk of the junction or the stop signal proper being over-run, while in some instances the advantage gained is still further enhanced where fast running occurs if a "through distant" be also provided under the "inner stop" to indicate the state of the route through the junction or station.

Finally, one or two words may be devoted to the question of the better distinction by night of distant signals, and the abolishment of the anomaly, existing under present conditions, of enacting that a red light is to be treated as a danger indication, at which a driver should stop, yet allowing such a light to be passed at speed, when it is affixed to a distant signal. Many suggestions have been made in this respect, and active steps are being taken to differentiate distant signals by using a fishtail lamp which practically reproduces in a white light the distinctive shape of the semaphore arm, but even this improvement does not remove the anomaly of the red light being disregarded as an absolute stop signal, and the plan adopted on the London Underground Railways of using a special orange light for distant signal lamps, when in the "on" position, appears to furnish the more satisfactory solution of the question, and would seem to merit a more extended application on the larger lines.

It is worthy of note that, in the United States, a yellow light was adopted twelve years ago for the "caution" indication; and at the present date a green light is used for the "clear" indication and a yellow light for "caution" on approximately one-half of the mileage of the railways of the United States and Canada.

Similar remarks may be made regarding the retention of red lights in dwarf signals, but it is satisfactory to observe in this instance, that a white light is now being largely used for such signals when in their normal position.

Although mechanical signalling has been brought to a high state of perfection, and for all ordinary purposes probably forms the cheapest type of control, both as regards first cost and future maintenance, yet, like all manual worked appliances, it has had to give way under exceptional circumstances to power-worked plants, of which several varying descriptions have been brought into practical use during recent years, and among which the following may be noted.

Westinghouse Electro-Pneumatic System.

In this system the signals, points, bars and locks are operated by motors worked by compressed air at a pressure of from 60

to 70 lb. per square inch, the valves of the motors being opened and closed by electric circuits controlled from the signal box.

A special feature of the system is that, in the case of levers working points, the full movement of the lever is not at once obtained, a lock on the lever arresting the full stroke. The initial movement only sets up the electric circuit which admits the compressed air to the motor, and when this has been done another circuit conveys the return indication of the movement to the box, releases the lock on the lever, and permits it to be pulled fully over, the complete operation taking only two seconds to accomplish. A similar procedure is followed when restoring a signal lever to a normal position in the frame, the movement not being completed until the return indication proves that the arm has properly assumed the danger position. These precautions eliminate all risk of failures of points or signals occurring without being detected, as in case of any movement being either partially or altogether impeded, the lever controlling the movement, and all other levers dependent on it, are immediately locked up, and continue locked until the impediment is removed.

A good instance of the practical working of this system may be cited at the Glasgow Central Station of the Caledonian Railway Company, where one signal box, containing 374 levers, controls the whole of the station.

The Siemens' "All-Electric" System.

In this system the operation of points and signals is effected by electrically worked motors controlled by switches forming part of the locking frame and connected thereto by suitable cables.

The mechanism for working points consists of a reversing motor, driving, through worm gear and a friction clutch, a shaft which carries a crank. In the case of trailing points the crank has an angular movement of about 150 degrees and is coupled direct to the tongues. The worm gear securely holds the points in either position, but the friction clutch allows them to be run through without damage to the connections, and should the points become jammed by stones, etc., during the movement, allows the motor to revolve, but without sending the return current to withdraw the check lock. For facing points, provided with locking bar and bolt, the crank has a movement of 320 degrees, and is coupled by a special rotary escape crank arrangement with both the bar and the points, the movements being as follows :—As the crank revolves the bar is first lifted, which in turn withdraws the bolt. The latter, however, is not clear of the stretcher rod until the bar has passed the middle position. Movement is then given to the points by the escape crank. The bar has meanwhile commenced its return stroke, and the bolt enters the

hole in the stretcher rod when the points are home. The motor circuit is automatically opened on the completion of each movement, the current being shunted through the detector contacts back to the cabin to operate the check lock.

The current required for working an ordinary pair of points of the heaviest rail section, together with facing point lock and bar, averages 4 amperes at 130 volts, the time taken for the complete movement being 2 to 3 seconds.

The semaphore signals are worked by a motor attached to the back of the post. The motor revolves a coupling magnet through a worm which gears into teeth formed on the magnet casting. The current received from the cabin passes through the coupling magnet in shunt with which is the motor having in its circuit a quick-break switch. The magnet, being energised, forms with its armature a magnetic clutch, thereby coupling the motor, through the worm gearing and pinion, to the signal arm. The motor, revolving, lowers the semaphore to a predetermined angle, at which point its circuit is opened by a switch. Its motion being arrested, but the magnet being still energised, the arm is held in the "off" position until the main circuit is opened. The signal then returns to danger by gravity, a contact giving a return indication to the cabin. A special safety device prevents the arm being lowered either accidentally or wilfully.

The current for working a signal averages 2 amperes during the movement, which takes 1½ seconds. The motor is then automatically cut out and the signal held off by the coupling magnet with a current of ¼ ampere until the lever is replaced in the frame. The locking frame is complete in itself, merely requiring to stand on the cabin floor, through which the cables to the points and signals have to pass. The height of the frame does not exceed four feet, and the width 12½ inches, the total weight being 40 lbs. per lever.

The system is being installed at the new G.W.R. Station at Snow Hill, Birmingham, where 300 levers will eventually be working, of which 124 levers have been in use for the past year.

Sykes' Electro-Mechanical System.

In this system the points are mechanically worked by levers grouped in a frame of the ordinary pattern, the signals being electrically operated by small slides placed immediately over the frame in the signal box.

The system has been installed at St. Enoch Station (G. & S.W. Railway), Glasgow, where 715 electrical slides are in use; at Victoria Station, London (L.B. & S.C. Rly.), where 377 slides have been fitted; and at Folkestone and St. John's to Orpington on the S.E. & C. Rly., where 277 slides are fixed.

The semaphore signals are actuated by motors, and the shunting signals by electric coils.

Automatic Signalling on the London Underground Railways.

This system of signalling, which has played so important a part in the success attending the electrification of the old steam-worked Metropolitan District Railway, was also perfected and installed by the Westinghouse Company, and enables a service of forty trains per hour to be maintained with commendable regularity.

Under this system, the automatically worked portions of the lines are divided into sections varying from nine hundred to four thousand feet in length by a special arrangement of track circuits, one of the running rails being divided into block sections by means of insulated fish plates, while the other rail is electrically continuous. A potential of from two to four volts is maintained between these two rails. At each end of a block section, a polarised relay is connected by one terminal to the block rail and by the other terminal to the continuously bonded rail. The local signal circuit is controlled by both relays, and unless both are suitably energised by a current in the normal direction, the signal cannot drop to clear. The entrance of a vehicle into the block section short-circuits one or both of the relays and the signal is placed at danger, and remains there as long as the section is occupied.

The chief feature of this system (Mr. H. G. Brown's patent, to whom acknowledgment is made for the description here given) is that currents extraneous to the signal system cannot affect the apparatus so as to cause a false indication of safety. When a train is in the section, one or other of the relays is always reversely energised or shunted, thus opening the local signal circuit at one or two points.

Each signal is governed by the section next in advance, and this section commences four hundred feet beyond the signal, and extends to a similar distance beyond the next signal. This length of four hundred feet is known as the "overlap" and a signal cannot be lowered until the whole of the preceding train has gone out of the section in advance, and has also passed the next signal by the length of the "overlap." This arrangement guards against a collision resulting through a signal being passed at danger, and a further safeguard is given by the automatic train-stops, which apply the continuous brakes if a train passes a danger signal.

Audible Signalling—The Driver's Cab Signal.

This invention is the outcome of an attempt on the part of several experienced railway officers to produce a signal of a reliable character which would inform the driver of a locomotive of the position of the stop-signals ahead of him, when atmos-

pheric conditions render it difficult, and sometimes impossible, for a sight of the semaphore arm to be obtained.

Since the inception of the idea, however, the scope of the invention has widened, and it is now found not only possible, but desirable, to make the driver's cab signal a substitute for the distant signal. The apparatus can also be fixed in tunnels, where an ordinary signal could not be placed, and could be used as a warning signal for temporary or permanent speed slacks.

At each point where it is desired to give an audible signal, an insulated ramp, consisting of a bar of T iron from forty to sixty feet long, is fixed in the centre of the four-foot way. The centre length of the bar is fixed at a height of four inches above rail level, the ends sloping off in either direction.

On each engine is placed a shoe, which normally stands two and a half inches above rail level, and which, on engaging with the ramp, is raised to the extent of one and a half inches. The shoe is insulated from the mass of the engine and, in its normal position, serves to complete an electrical circuit, but when it is raised, by passing over the ramp, this circuit is broken and a steam whistle liberated, thus giving the driver an audible " danger " or " warning " signal.

If the signalman desires to convey an " alright " or " clear " signal, a current is passed from the signal box to the ramp which completes an alternative circuit on the engine, prevents the whistle being liberated and, instead thereof, rings an electric bell, thus giving an audible " clear " signal. Visual indications are also given in the engine cab corresponding with the audible signals.

For single-line working a special arrangement is used whereby the signalman is compelled by the interlocking to cancel or neutralise the ramp not applying to the direction in which a train is travelling, by withdrawing an electric staff or tablet from the instrument; and when the staff has been withdrawn, the special lever for cancelling the ramp is back-locked until the staff has been restored at one end or the other. The system has been introduced on the Great Western Railway.

Track Circuits.

Recent events have unhappily brought into prominence the liability of the human element in signal operations to err, when movements are not actually controlled by mechanical agencies, and a brief reference may perhaps be made to the advantages obtained by installing track circuits at spots where special protection is required.

At stations, where a clear view of all the roads is not possible from the signal box; or at large depots, where shunting operations have to be carried out in conjunction with the ordinary traffic, the provision of track circuits prevents the presence of

a train or vehicle, on any line so treated, being temporarily overlooked, or the admission under block working of another train into the section.

At junctions, or other spots where lines cross or foul one another, the provision of circuiting automatically effects a safe measure of control over all movements, and where short sections occur, which preclude the erection of advance signals, the extension of the circuit for a short distance beyond the junction gives an overlap, or safety length, which must be passed by the last carriage before the signalman can plunge back and accept another train.

Widenings and Enlargements.

The initial trunk lines consisted almost entirely of two lines of rails only, and for some years were found equal to the traffic passing over them. The multiplication of branch lines and the development of all classes of traffic, however, in many cases taxed the resources of the main systems to their maximum carrying capacity, and, combined with the growing speed of long-distance trains, necessitated the laying down of additional lines. In the course of time, also, many of the larger stations, especially the terminal ones, were found unequal to accommodating the growth of traffic, although the foresight of not a few of the original promoters on this latter point may, perhaps, be regarded as one of the most satisfactory features of earlier railway planning.

On the first of these heads it is not possible to refer to many points that arise in the consideration and scheming of railway widenings, but one or two observations may be made on the general principles of the works, and the location of the new lines in relation to the existing railway.

Assuming that the traffic on a certain length of ordinary double-line railway has outgrown the economical carrying capacity of the same (which capacity often falls short of the actual capabilities of the line), the first point to be determined will be as to whether the required relief could be better given by widening the existing line, or by constructing a new and independent line over which a portion of the traffic could be diverted.

In many cases the earlier railways could not, from circumstances entirely beyond the control of their projectors, be made either on the best routes or on satisfactory gradients, and this may lead to a widening scheme being abandoned in favour of the construction of a new ıailway which, in addition to giving a better working route, may have the effect of opening out fresh country, or of reducing the distance between important trade centres on the system.

Confining the question, however, to widenings only, the character and density of the traffic, as well as the physical

conditions obtaining on the railway, require close consideration, as either of these items may strongly influence the general outline of the new scheme.

If goods or mineral traffic predominates, it may be found desirable to construct relief lines for that traffic wholly on one side of the existing railway, thus probably avoiding interference with the passenger stations ; but if the additional lines are required to serve both passenger and goods traffic, the arrangement of the new works is a more complex matter to solve.

Under the last-mentioned conditions, the ideal type of a four-track railway is, perhaps, one having adjacent lines for each direction of traffic, as opposed to a track on which the directions alternate. With the former type, a single island platform between each set of lines at stations effectually separates the traffic in either direction, at the same time enabling both of the lines to serve the platform. This type of location also admits of branch lines being connected to the main system without fouling the fast centre lines, the converging branch line being led direct into one of the outside or slow-traffic roads, while the diverging line is carried by a flying junction either over or under the main system. In the alternative case, if island platforms were provided, each platform would serve either direction of traffic, thus probably causing the frequent transfer of passengers and luggage from one platform to the other. A third way of dealing with the question consists of providing platforms to serve the outside roads only, the two centre roads being devoted to fast traffic and carried through the station without platform accommodation.

The general plan of the intended works will probably also be greatly influenced, if not altogether governed, by the price at which land can be acquired. In the event of the conditions being reasonable, sufficient property will be bought to give the required extra width, but if such a step would lead to an excessive expenditure, the extra formation width will be obtained as far as possible by constructing retaining walls, thus limiting land purchase to such spots where no other scheme is practicable.

If the retaining wall plan be adopted to any great extent, the widening will, in the majority of cases, be effected by providing an extra single line width on each side of the existing railway, a course which practically necessitates the retention of the present curves and gradients, and prevents any improvement thereof being carried out. On the other hand, if land be acquired throughout, and the new works are planned with a view to affecting any easement of curvature or gradient that may be possible, the future running on the line may be improved without incurring any prohibitive expense.

Unless physical or other reasons prevail to the contrary, it

is suggested that widening works should be carried out as far as possible on one side only of the railway, as such a plan ensures the minimum interference with the existing earthworks and limits the number of land purchases. Except also as regards the reconstruction of over bridges, the existing lines of rails are more effectually isolated from the contract works. While observing this suggestion in the spirit, it may often be found both desirable and economical to plan the widening on alternate sides of the main system, the lines being slewed into their final position on the completion of the work. Such procedure may enable any particularly expensive stretches of property to be avoided and obviate interference with certain works which it may appear politic not to disturb, as well as affording means of improving the curvature of the line, as has been previously mentioned.

The Board of Trade regulations require a space of ten feet to be left where additional running lines are laid down adjoining existing running lines; and, in the case of the conversion of a double line of railway into a four-track route by constructing the additional lines entirely on one side of the present lines, the requirement is perhaps best met by providing the extra space in the centre between the two sets of rails, as that plan leaves space for the piers of over bridges and the main girders of under bridges, and also provides room for a good surface water drain along the centre of the formation.

In the case of a widening being effected on each side of the existing railway, the extra space will probably have to be given on either side between the new and the old lines, but in whatever way the requirement is met, every effort should be made to keep the fast-traffic lines as straight as possible, any extra curvature that may be necessitated at bridges or other works being carried out on the slow-traffic roads.

The acquisition of powers for widening a railway generally entails the reconstruction of many of the public road bridges crossing under and over the system, and may compel the abolishment of both public road and occupation level crossings. In dealing with girder bridges it will be found the better policy, so far as the future maintenance or renewal of the structures is concerned, to plan the work so that one half of the bridge can be effectively handled without interfering with the other, thus ensuring that two lines of rails will always be open to traffic.

The widening of a railway in a town area, or in the vicinity of a terminal station, brings forward many features that are naturally controlled by the special conditions obtaining at the spot, but on general grounds a terminal widening and the enlargement of a terminal station are so closely connected with one another, that the two works may with advantage be considered together.

It has previously been remarked that one of the more satisfactory features of earlier railway promotion was the foresight shown in providing terminal stations having an area which has, in many cases, allowed of considerable extensions being made—this feature, however, if more closely looked into reveals the fact that the extra space was in some instances initially given for the storing of coaching stock at the station itself, rather than with a view to providing for extra platform accommodation. The extra areas, have nevertheless, proved of great value in enabling the first remodelling of many large stations to be taken in hand by establishing carriage depots at a spot a little removed from the stations, and utilizing the space, thus freed, for platforms and extra lines.

If further enquiry is made, it will generally be found that the first remodelling of the large stations was followed, at a date varying with the increase of traffic, by widenings of the more immediate approach lines and, at a still later date, by the extension or reconstruction of the stations proper. This last step has not yet been reached in all cases, and may be deferred for some time, owing to the changes which are maturing as regards local traffic.

The intermediate step of widening the approach lines is, perhaps, an almost more important work than the actual extension of the station itself, as, without a good approach, the working of the best planned station must be resticted, and its real value reduced.

As regards the number and arrangement of the approach lines iequired to deal expeditiously with terminal traffic, conditions will, of course, vary with different descriptions of traffic, but on broad grounds it will generally be found that more satisfactory working is obtained if the "outward" lines are slightly in excess of the "inward," the reason assigned being that, although the actual number of "out" and "in" loaded trains throughout the day may exactly balance, yet the two densest volumes of traffic usually occur in the morning, when empty trains have to be quickly worked away from the station conjointly with the ordinary "out" service, and in the early evening, when the heavy "out" traffic is, as a rule, concentrated into a shorter period than the corresponding "in" traffic during the morning. On one of the London railways this problem of concentrated traffic has been ingeniously met by establishing reversible working on the centre line of a three-way track, the line being used for up traffic in the morning, and for down traffic during the evening, separate signals being provided for each direction, and the extension of this type of working might afford great relief on other congested lengths, and considerably increase their carrying capacity at a comparatively low cost.

The arrangement of the approach lines and their allocation

to the different classes of traffic to be served must largely be a question for individual consideration, but each line should have direct access to as many of the platforms as possible, the connections being planned so as to enable an outgoing train to reach its proper running line quickly, thus freeing the platform roads without delay, and assisting the inward traffic by reducing the distance between the station stop signals and the platforms.

The provision of a thoroughly good approach to a terminal station may often enable the enlargement of the station itself to be postponed beyond a date which would not otherwise have been prudent or economical, but the improvements effected to the approach will always be planned with due regard to the ultimate reconstruction or extension of the station, thus saving any second expenditure of capital over one area of ground.

In the matter of terminal stations, which have not yet undergone reconstruction, it will often be observed that the factor which principally limits the proper handling of traffic consists of the short length and narrow width of the majority of the platforms therein. The original design of many of these stations comprised the provision of a single arrival and departure platform, of more or less ample length, on either side, but if other platforms were formed in the central immediate space, or have been added from time to time as traffic increased their length and width were determined more by the conditions then existing than with a view to future working, with a result that their user is much restricted under present-day requirements.

Opinion is somewhat divided as to what extent the various platforms of a large station should be definitely allocated to the different classes of traffic, but on general grounds it is suggested that the majority of the platforms should be available for all traffic, and that a station, having a smaller number of really good platforms, conduces to better working results than does a station having a larger number of platforms of only moderate length and width.

Electric Traction.

Following on the preceding remarks respecting the widening and enlargement of existing railways and terminal stations for dealing with the increasing volume of traffic, the subject of electric traction may be appropriately considered and a brief reference made to one or two points connected with the application of that type of traction to steam-worked lines.

In nearly all large towns, and especially in or around London, the habits of the travelling population have considerably altered during the past few years. New districts have been developed

with the result that three distinct zones or areas of travel have to be provided for, which may be described as :—

(*a*) The inner Metropolitan area, contained roughly within the four miles radius.

(*b*) The outer Metropolitan area, extending to a radius of from ten to twelve miles.

(*c*) The new residential districts adjoining a line of railway, which are now being developed, and which may extend as far as twenty-five miles from a terminal station.

On the first inauguration of the railway systems entering London a purely local service of trains served area (*a*) and the inner portions of area (*b*), while the outer portion of (*b*) and the area (*c*) were adequately dealt with by the slower trains on the main lines. In course of time the growth of area (*b*) demanded the provision of a separate service, which has since been considerably increased as the population tended to migrate to the outer districts, while the local traffic in area (*a*) has been largely transferred to outside competitive carrying agencies in the shape of tramways and motor busses.

The above facts were doubtless fully in the minds of the Royal Commission on London Traffic, who reported as follows :—

"It is, we think, evident that the introduction of electric "traction will lead to a great improvement of suburban and "urban railway facilities in London. The speed of all trains "worked by electricity, especially those which stop at many "stations, will show substantial increase over the speed of steam "trains. It will, we believe, also be found that electric traction, "apart from its other advantages, will enable railway companies "to increase the number of trains working in and out of the "terminal stations, and thereby add largely to the facilities "afforded for suburban traffic."

The electrifications already carried out on the English and Continental railways show that it is an undoubted fact that the higher rate of acceleration which is possible as compared with steam working, greatly increases the average speed for station to station traffic, and, if motor-driven trains are employed, the movements at a terminal station are practically reduced to actual arrival and departure, thus adding considerably to the carrying capacity of any section of a line so equipped. The practicability of electric traction may, therefore, be accepted, and the question of its application resolves itself rather into a matter of expediency, capital cost and upkeep.

If the operating expenses of steam-worked railways are looked into, two facts of primary importance present themselves, first, that the cost of locomotive power forms a very appreciable proportion (approximately 30 per cent.) of the total trans-

portation cost, and if the details of this cost are analyzed the second fact is established that the unit cost of conducting a suburban service, with frequent stops and delays at terminal stations, is much higher than the unit cost for long-distance services.

If the operating conditions are next examined it will generally be admitted that perhaps the most important problem which the transportation officer is just now being called on to solve is the conduct of local traffic on a system which also serves outer districts, and has, in addition, a main-line service of any extent to maintain, the problem being in many cases accentuated by the fact, previously referred to, that such traffic has to be conducted in competition with outside carrying agencies which did not exist when the railway was first constructed.

If satisfactory results are to be obtained from this type of traffic, it is essential that the service should be a frequent and expeditious one, and, if such conditions are not economically obtained under steam working, a company may seriously have to consider whether the application of electric traction would meet the question and, if so, whether the service is capable of being furnished without detriment to the remainder of the traffic on the railway.

To justify the partial adoption of any alternative mode of traction on an existing railway needs almost closer consideration than would the question of the entire conversion of a system, as, with two independent sources of power, the risk arises of one, or possibly both sources, not being worked to a degree that approaches full economy.

In the case of a purely suburban line, which is independent of main-line trains, and on which traffic is capable of being created by the provision of an improved service, the recommendation of the Commission may hold good, but in other districts where competitive carrying agencies exist, or are about to be established, the outlook may not be so favourable, as it must be borne in mind that acceleration, and a more frequent service, entails additional working expenses, to which have to be added the interest charges on the capital expenditure in giving the service, so that, to ensure financial success, not only must the whole of the existing traffic be retained, but an accretion of receipts is also required to meet the extra expenditure.

On broad grounds, therefore, the factor that perhaps marks the real balance of the question is the fixing of a point or points on a railway, above which (reckoning from the terminal station) the fostering of local traffic is not likely to prove remunerative under steam working, but below which the provision of increased and improved facilities promises successful results, the prospects in the latter case being naturally enhanced if the upper end of the line is not monopolised by barely paying short-distance trains.

Having established this dividing point, the engineer, in conjunction with the other responsible officers, has next to consider to what extent or for what period the existing lines and stations will accommodate the altered conditions, and, in the event of congestion being feared, if the required relief is likely to be better given by adopting electric traction on the existing lines, to an extent that would not act detrimentally on the longer distance steam-worked traffic, or by widening the railway so as to provide increased means for thoroughly dealing with an electrically worked local service, which might reasonably be expected to hold its own with all outside competitive agencies, and at the same time allow of the longer distance traffic being properly developed under steam working.

The consideration of these matters needs particular thought, and will entail much investigation into several side issues which are closely bound up with the terminal working of a railway. Of these issues, the future influx of traffic from newly opened districts is not the least important, and it behoves all who have, or are likely to have, to deal with the question, to acquire a thorough knowledge of the altered conditions that are now attaching themselves to the travelling public.

The conversion of the Metropolitan and Metropolitan District Railways has shown what a greatly improved service can be obtained from electric traction on station-to-station lines, while the inception and subsequent spread of tube railways is to be directly ascribed to the special facilities afforded by that type of motive power, and future developments of this form of traction will be watched with close interest by all engaged on the larger question of the provision of additional accommodation on the main railway systems.

The concluding lines of this address will be devoted to an appeal for the thorough co-operation of the members generally in assisting to further the work of the Society, and so make membership not only of more practical value individually, but also a state to be more desired by reason of its accruing benefits.

Mere increase in membership, without a corresponding increase in practical co-operation, is not to be advocated if the Society is to fulfil its true mission. Better for a smaller, yet compact and active body, with each unit endeavouring to do something for the common good, than numerical strength only, without pride in membership, or a wish to raise the status of the profession.

Frequent requests have been made in the past for more regular attendance at the meetings, while the financial side of the Society's work would greatly benefit, and the officers be enabled to devote their time to more deserving objects, if increased attention were given to the due payment of subscriptions,

and although each of these subjects should, and the Council feel sure will, engage proper consideration, it is not proposed in this instance to dwell thereon, but rather to make a special appeal for the better support of the JOURNAL, which is certainly capable of being much enlarged and improved if a more thorough spirit of co-operation can be assured.

The monthly issue of the JOURNAL affords means to outlying Members of communicating their views on the subjects brought forward, and also of opening out fresh lines of thought, which were not possible under the former publication of a yearly volume, and as knowledge is best advanced by the free exchange of experience, the cordial assistance of members in this respect is earnestly invited.

The spread of knowledge in connection with the many and far-reaching works undertaken by the engineer for the benefit of humanity, demands a united and steadily maintained effort, and among the varying channels through which that knowledge may be conveyed a place has been reserved for our own Society, which must not, and will not, fail in faithfully and efficiently carrying out its duties.

Mr. J. W. Wilson said that as Senior Past President it fell to his lot to propose a vote of thanks to the President for his address; and he was sure the meeting would support the vote. It was a great advantage for the Society when a new President would prepare such a useful address, dealing not only with generalities, but also with a branch of the profession in which he occupied a distinguished position, as Mr. Bloyd did. In such a case the President brought before the Society not only matters of theoretical interest, but also his own extensive practical experience as affecting them; and it was by such means that engineers were enabled to arrive at useful results. It was not the custom to discuss the Presidential Address, but he could not help feeling that if it had been a paper submitted to the Society for discussion it would certainly have obtained the President's medal because of its general and special interest. Mr. Bloyd had given many examples of what was being done at the present time; and to the electrification question he had devoted some wise and well considered remarks. The great development which was taking place in this direction upon railways would, he hoped, counteract to some extent what he could not help saying was the unfair competition which many of the railways had had to face. When he began to work at the Crystal Palace, thirty-eight years ago, people thought nothing of sitting in a train for three-quarters of an hour in going there from Victoria to hear a Saturday concert, but they were not satisfied with that now. They wanted to go in a quarter of an hour, and they did not wish to trouble about going for any particular train. The time was, indeed, said to be

approaching when they would be able to get to Brighton in twenty minutes, so that without entrenching on anything more than the dinner hour, they would be able to leave Victoria, travel to Brighton, lunch in the train, have a swim and get back at two o'clock. Things had not yet been taken quite as far as that, but he hoped that Mr. Bloyd would live to see it carried out.

Now that the Society were to hold their meetings in the excellent room they were at present occupying, through the generosity of the Institution of Electrical Engineers, he hoped that they would see a larger attendance at their meetings and he felt sure that they would support the appeal which with Mr. Bloyd ended his address. Thanks to their immediate past President, ably backed up by Mr. Ackermann, and he thought he might say, warmly supported by the members of the Council, a large amount of energy had been brought to bear upon the Society, and they ought now, at the outset of a new year, to co-operate thoroughly together so that they might render the Society still more important even than it was at the present time. They called themselves a "Society" and not an "Institution." There was something rather cold-blooded about an institution, whereas there was something warm-blooded about a Society. The members felt among themselves that they were on a friendly footing together, and he could assure the meeting that the Council and their officers did everything they could to promote the welfare and prosperity, not only of the Society generally, but of every individual member. He therefore hoped that they would all help in the great improvement that was taking place. Mr. Bloyd had taken the trouble to prepare an excellent Presidential address, and the members would read it fully with still more interest. He was sure they would support Mr. Bloyd in every way they could, so that he might have a very successful year of office, upon he which he would look back in future times as one of the happiest periods of his professional life.

Mr. Percy Griffith seconded the motion. He said that Mr. Bloyd was a very old friend of his, and that, if he was not also a personal friend of the other members, the fault was theirs. If they attended the meetings during Mr. Bloyd's year of office they would find that he would be very anxious and ready to shake hands with them, to welcome them, and to make them feel that this was a "Society" rather than an "Institution." Co-operation seemed to be the order of the day, and the President had very wisely directed attention to this subject. They had one example of combination in the case of the railway in which the President was interested. They could all remember the time when there was a London, Chatham and Dover Railway and a South-Eastern Railway, and when they were mutually doing each other and the passengers very much damage ; but now

the two companies had united to the mutual advantage of the shareholders and the passengers of both companies.

This Society had passed through a similar change, and, although the result had not been proved to the same extent as in the case of the railways to which he had referred, the two Societies which had amalgamated were in a fair way towards finding similar advantages.

There was another form of amalgamation which he wished to commend to the members, which the President had called "co-operation." They might take that as a distinct invitation from the Chair that there should be a more distinct union between the Officers, the Council, and the members of the Society ; and, if the President's year of office was marked by an increase of cordiality between the Council and the members, they would have made a very important step in advance.

The excellence of the work which would be done by the amalgamated Society might, he thought, be fairly judged by the excellence of the address to which they had listened. That address proved that Mr. Bloyd was a man of unusual merit as an engineer, and he (Mr. Griffith) thought that it might be said that a good engineer was a good man all round. In asking them to welcome the address he should be asking them to welcome the President. The address had shown that Mr. Bloyd knew as much about water-works as about any other branch of engineering connected with railway work, and although this meant that a water engineer like himself must take a back seat, any Past-President would be pleased to see a successor showing greater qualifications for the Presidency than he had. The address was rather a lecture than a Presidential address, and, as such, the premium which should be awarded to it would be far beyond the resources of the Society. One subject mentioned in the address, viz. :—that of legislation, was of peculiar interest to him and might be so to others. It was a very remarkable fact that the years 1845, 1860, 1863, and 1870, were marked by special legislation with regard to railways ; as the special legislation of those years affected a great many other branches of engineering. Of course the Companies Act and the Land Clauses Act of 1845 applied to many other undertakings besides railways But in 1863 and 1870, whereas special Acts were passed for railways, at the same time several very important special Acts were passed for other engineering works. He ventured to think that the legislators of those days must have been more active than legislators were to-day. Probably they were not concerned so much with purely political subjects ; but, whatever the reason was, they carried out more practical and useful legislation than the legislators of to-day. In fact, many recent Acts dealing with engineering seemed to have proved failures. The Light Railways Acts and what he might describe as the Railways "Facilities"

Act of 1870 had not been very successful, whereas similar Acts with regard to gasworks and waterworks had been entirely successful.

He must apologise for having spoken so long, but there was such a great amount of useful information in the address that it had inspired him with many ideas which he was utterly unable to express adequately; he hoped, however, that he had said enough to lead the meeting to accord the address the enthusiastic reception which it deserved.

The motion was put to the meeting by the mover and carried by acclamation.

The President said that he was very much obliged to the members for the manner in which they had received the vote of thanks. He had been rather afraid that his address might fall below the usual standard of merit, because an engineer who was employed by a large corporation like a railway company did not have the same advantage in presenting descriptions of work as, say, a consulting engineer. There were other matters which he should have liked to bring to the attention of the Society, and he hoped that he might be able during his year of office to secure papers upon them. He also had great hopes of securing papers on signalling and permanent way, both of which were most interesting subjects and admitted of more detailed treatment than the limits of the address allowed. Personally he should do all in his power to further the work of the Society.

6*th March*, 1911.

F. G. BLOYD, PRESIDENT, IN THE CHAIR.

PETROL AIR GAS.

By E. SCOTT-SNELL.

[ASSOCIATE MEMBER OF COUNCIL.]

DURING the last few years the problem of lighting places in the country outside the radius of the gas or electric light supply has received considerable attention from inventors. The increased facilities for obtaining petrol, due to the growing demand for this fuel for motor cars, has led experimenters to investigate its possibilities as a medium for producing gas for lighting places which have no central source of illumination.

The idea of supplying carburetted air for lighting purposes is nearly a century old, but was of no value from a practical point of view until the introduction of the incandescent mantle made it possible to use a gas which was comparatively weak in hydrocarbon and had no particular lighting value *per se*. The failure of the old machines was due to the exceedingly high cost of the light when obtained from a luminous flame (necessitating as it does the use of a gas very rich in hydrocarbon), and also to the fact that a gas so rich in vapour could not hold its vapour at temperatures as low as those often met with in practice, with the result that the petrol was deposited in the pipes and lost substantially in illuminating power. But the introduction of the incandescent mantle allowed the use of a gas which had no pretensions to illuminating power but was a gas whose sole function was to supply the highest possible temperature at the point of combustion. In fact a gas so low in petrol vapour as $1\frac{1}{2}\%$ can be used, whereas the old flat-flame system demanded a gas containing about 12% to be of any use. The best proportions of vapour to air the author considers to be between 6 and 10%, the reason for which he will endeavour to show in the following pages.

To arrive at any conclusion as to the best mixture to employ one must consider, side by side with the laws of evaporation and the physical properties of the hydrocarbon used, the conditions the gas must fulfil in actual practice. The main feature of the gas must be its inability to deposit petrol in the system at any temperature it may meet with in the service on its way to the burners, and the next consideration, the author considers, should be the impossibility of combustion of the gas in the system

itself, *i.e.*, one should if possible deliver a gas which insures that even if the gauze of a burner perish or a flame in any way be carried back into the service, explosion of the apparatus would be impossible. The following considerations are essential in examining the proportions which fulfil these conditions.

Petrol consists in the main of the lighter hydrocarbons of the paraffin series having the formula C_nH_{2n+2}; in fact the petrol used for lighting purposes consists almost exclusively of pentane (C_5H_{12}), hexane (C_6H_{14}), heptane (C_7H_{16}), and traces of octane (C_8H_{18}), in varying proportions according to the specific gravity and source of the fuel. For instance from an analysis given by the Anglo-American Oil Co. their "Anglo-Special Spirit for Gas Making," sp. gr. 0·680, upon fractional distillation comes over as follows :—

Probable composition judging from boiling points.

1%	at	50° C.	Pentane and Hexane.
27%	,,	60° ,,	
28%	,,	70° ,,	Hexane.
19%	,,	80° ,,	Hexane and Heptane.
12%	,,	90° ,,	
6%	,,	100° ,,	Heptane.
3·5%	,,	106° ,,	Heptane and Octane.

As the highest efficiency is given by a mantle when raised to incandescence by a gas which gives the highest possible temperature at the point of combustion, and this is synonymous with the mixture giving complete combustion, it is easy to find this mixture from theoretical considerations. Taking hexane, which is the most important constituent of the petrol used for lighting purposes, the equation of complete combustion is as follows :— $2\,C_6H_{14} + 19\,O_2 = 12\,CO_2 + 14\,H_2O$
from which we gather that

2 vols. of vapour require 19 vols, of oxygen
contained in $(19 \times 4{\cdot}81 =)$ 91·3 vols. air

$$\therefore\ 100 \text{ vols. mixture contain } \frac{200}{92{\cdot}3} = 2{\cdot}17\% \text{ of vapour.}$$

Similar calculations give as the mixtures for complete combustion

Pentane	sp. gr.	0·626	2·53% by volume.
Hexane	,, ,,	0·663	2·17% ,, ,,
Heptane	,, ,,	0·688	1·86% ,, ,,
Octane	,, ,,	0·719	1·64% ,, ,,

Anyone acquainted with the theoretical aspect of internal combustion engines knows that the greatest explosive effort is given with substantially this mixture of air and vapour. In practice slightly more air is used to ensure complete combustion. The undesirability, then, of supplying this gas direct through the pipes is obvious, although it is exactly the mixture required at

the mantle. Practically all plants used for making this gas employ a gasometer to store a certain amount of it, either for direct use or for governing the apparatus relatively to the demand, and if fired by accident this is likely to "give furiously to think." The author has seen the results of an explosion of this kind which were, to say the least of it, impressive.

Experiment shows, however, that the upper limit of combustibility (without the addition of further air) is reached when the amount of petrol vapour in the mixture is 6% or over (Redwood puts it at 5%, Sorel at 4%) and it is impossible to fire such a mixture in the pipes and gasholder. In fact it behaves in exactly the same way as coal gas and is absolutely safe from the danger of explosion in the system itself.

Evidently, then, to be safe we must use a mixture of not less than 6% and dilute it to the desired proportions for complete combustion at the burner head by a burner of the Bunsen type. We are immediately brought to the question of how much richer than 6% we may allow our gas to be. This is governed by the necessity of fulfilment of the first of our essential conditions, viz., that the gas must not deposit petrol in the pipes under any conditions of temperature likely to be met with in an installation. If we find what is the richest mixture stable under these conditions we shall have all our factors satisfied if we strike a balance between this and the upper combustible limit, thus giving a margin either way.

As the gas is usually generated in an outhouse, and may have to traverse a section of piping exposed to frost, one ought to employ a gas stable at some degrees below freezing point, *i.e.* a gas which does not become "saturated" until a fairly low temperature is reached. In dealing with this point the author proposes to set out the laws of evaporation at some length, excusing himself on the ground that the matter is only dealt with in the more advanced textbooks, and then only in reference to hygrometry and in such a way as to make it very difficult to grasp for a person approaching the subject for the first time. In the author's opinion there is room for a more simple exposition applied to the case in point. The theory is based upon Dalton's classic experiments on mixtures of gas and vapour. The conclusions he came to (which have been found correct except in special circumstances) were :—

(1) That in a space which contains a liquid and its vapour the liquid will evaporate only until the pressure of its vapour attains a definite value dependent upon temperature only.

(2) That in a space containing dry air or other gas or gases a liquid will continue to evaporate until the pressure exerted by its vapour alone is the same as if no air or other gas were present.

(3) That in any mixture the total pressure is equal to the sum of the pressures that each constituent would exert if it occupied the space alone.

The last two laws are only true in the case where the liquids are not mutually soluble. When the liquids are completely miscible, as for instance the various constituents of commercial petrol, the sum of the vapour pressures will be less than the sum of the separate vapour pressures, but its value is more easy to determine by direct experiment than to predict from theoretical considerations alone. In this connection the curves given in Fig. 3 are of interest when considered in connection with Table A.

The foregoing, however, does not affect the following reasoning :—

Suppose we have 100 cubic metres of air and vapour at 760 m/m pressure and t° C. of which x cubic feet is vapour. The latter *will behave as if* it occupied the whole space alone, *i.e.* as if it had a pressure due to expanding from x cubic metres at 760 m/m and t° C. to 100 cubic metres at t° C. This pressure would therefore be

$$760 \times \frac{x}{100}$$

If we know the vapour pressure p at the temperature t° C. (as we often do from vapour-pressure determinations) we have

$$p = 760 \times \frac{x}{100}$$

from which we get $x = 100 \times \frac{p}{760}$ .... (1)

It follows from the first law that such a mixture is not on the point of condensing part of its vapour unless p is the pressure of the saturated vapour corresponding to that particular temperature. Hence the condition of stability, or otherwise, is known if we know the pressure of the vapour in the mixture and the saturation temperature corresponding to this pressure. Figs. 1, 2, and 3 are curves plotted from experimental figures obtained by Young for pentane and heptane, and by Sorel for hexane and the commercial petrols marked A, B, C, and D.

In practice we usually know the composition of a mixture in the form of a certain weight of petrol evaporated into a certain volume of air, hence we require for convenience a formula which will give us the vapour pressure directly from these data.

Suppose our mixture consists of 1 kg. of vapour to V cubic metres of air measured at t° C. and 760 m/m and we want to know the vapour pressure p.

From (1) any mixture in which the pressure of the vapour is p contains

$\frac{p}{760}$ cubic metres of vapour to $\frac{760 - p}{760}$ cubic metres air

i.e. if d is the weight in kgs. of one cubic metre of vapour

$\frac{pd}{760}$ kg. vapour to $\frac{760 - p}{760}$ cubic metres of air,

i.e. 1 kg. vapour to $\frac{760 - p}{pd}$ cubic metres air.

and if V is the volume of air evaporating 1 kg. of petrol in this case, then

$$V = \frac{760 - p}{pd}$$

from which

$$p = \frac{760}{1 + Vd} \quad \ldots\ldots\ldots \quad (2)$$

or expressed in English units

$$p = \frac{760}{1 + \frac{V}{F}} \quad \ldots\ldots\ldots \quad (3)$$

where V = cubic feet of air evaporating one gallon of spirit and F = cubic feet of vapour given by one gallon of the spirit.

For example, for the complete combustion of hexane as given by the formula $2\,C_6\,H_{14} + 19\,O_2 = 12\,CO_2 + 14\,H_2O$:—

2×86 kg. of spirit require $19 \times 22{\cdot}4 \times 4{\cdot}81$ cubic metres of air at 0° C. and 760 m/m, *i.e.* 11·9 cubic metres of air per kg. of spirit. The density of hexane vapour is

$$\frac{86}{22{\cdot}4} = 3{\cdot}84 \text{ kg. per cubic metre.}$$

From equation (3) we get $p = \frac{760}{1 + 11{\cdot}9 \times 3{\cdot}84} = 16{\cdot}3$ m/m.

and a reference to Fig. 1 will show that such a mixture should not deposit any vapour until a temperature of – 18° C. is reached.

As we often want to know what is the percentage composition of a mixture formed by evaporating a certain weight of petrol into a certain volume of air the following formula may be of value. It is obtained by substituting the value of p in equation (2) in equation (1), from which we get

$$\text{Vols. per cent.} = \frac{100}{1 + Vd} \quad \ldots\ldots\ldots \quad (4)$$

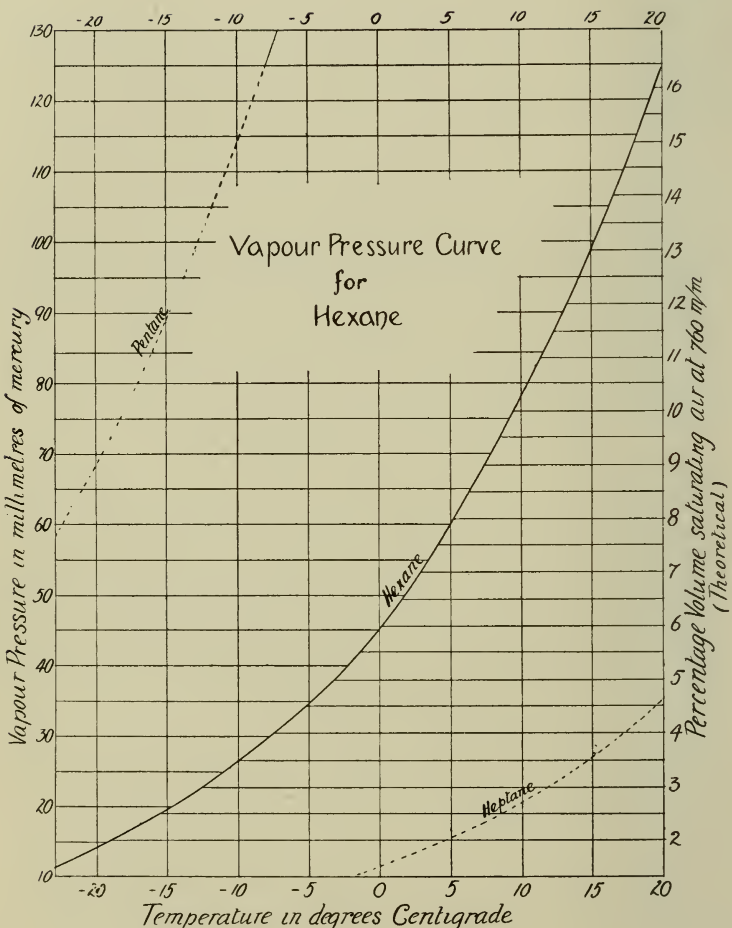
or in English units with the same notation as before

$$\text{Vols. per cent.} = \frac{100}{1 + \frac{V}{F}} \quad \ldots\ldots\ldots \quad (5)$$

As has been previously pointed out, if we wish to employ a gas which is not explosive in the apparatus it must contain say 6% of vapour. In a 6% mixture the vapour pressure is

$$\frac{6}{100} \times 760 = 45{\cdot}6 \text{ m/m.}$$

and if this vapour is hexane, from the vapour pressure curve we see that it would be saturated at freezing point. The experimental figure of 5% for the upper limit of combustibility however, given above, refers to petrol (*i.e.* a mixture of several hydrocarbons). In the curve D (Fig. 3), for instance, the vapour pressure at 0° C. is 99 m/m, so that air at this temperature could hold



Vapour Pressure Curve
for
Hexane
Pentane
Hexane
Heptane
Vapour Pressure in millimetres of mercury
Percentage Volume saturating air at 760 m/m
(Theoretical)
Temperature in degrees Centigrade

FIG I

$$100 \times \frac{99}{760} = 13\%.$$

Unfortunately none of these curves for mixtures are extended below freezing point but we should be justified in assuming that if a 13% mixture is stable at 0° C., a 6% mixture is stable at many degrees lower.

The author made some experiments on condensation with a 6% gas made from Anglo-Special spirit of sp. gr. 0·680 and found that at 0° C. there was a faint deposit (a dew-point instrument had to be employed to indicate this) but that the gas could be run through a coil of pipe kept at –10° C. by a freezing mixture without a deposit of any appreciable magnitude, in fact the gas was kept burning in a Bunsen burner for some hours with the coil at this temperature. The small quantity that was condensed had quite a different smell from that usually associated with petrol and was very heavy, having a sp. gr. of about 0·760. This latter figure was very difficult to determine owing to the minute quantity available and the writer would not vouch for its accuracy. In order to discover the condensing point with regard only to the petrol, the gas was dried by passing over calcium chloride before passing into the freezing mixture.

As the piping in any installation is usually either sunk in the ground, or inside the house, a very low temperature will hardly ever be met with in practice, so that trouble from condensation of a 6% gas need not be expected. One is always more likely to find water in the pipes than petrol, but this depends to a great extent upon the design of the machine, particularly in respect to methods of carburation. The deposition of water in the pipes is not of any great importance as it can always be removed from syphon boxes in any properly designed installation, but the deposition of petrol means a loss of heating value from the gas and may even become a source of danger if it can leak through the joints. The author would like to state here that in an experience of five years of work in connection with petrol gas he has never come across petrol in pipes except in a case where heavy motor car petrol was used and carburation was effected at a temperature very much above normal.

The foregoing arguments show that there is no objection to a rich non-explosive mixture provided it is not too rich. Most makers of petrol gas apparatus, however, seem to prefer a mixture in which all the air for combustion is sent through the pipes and none taken in at the burner. This is of course a violently explosive mixture in the gasholder, which may be fired if a flame can by any accident flash back along the pipes. Hence these manufacturers have to take the most stringent precautions against this possibility and to this end their burners are choked up with fine gauze or similar dust-collecting material and there are, or should be, sets of gauzes at the exit from the machine into the service.

It may be argued that in a machine making a non-explosive gas the possibility of failure of the petrol supply may cause it to become explosive. This is a perfectly fair contention and it would therefore be well to examine the possibility of trouble should this occur.

It is an essential of efficiency that the gas at the point of ignition should be a self-burning one *i.e.* an explosive mixture, and when using a rich non-explosive gas this effect is obtained locally by means of a Bunsen burner—the gas issuing from a small nipple and drawing in a further supply of air on its way to the burner head. Obviously then, if a rich gas in the service produces an explosive mixture at the point of combustion (*i.e.*, about 2% of vapour to air) an explosive gas in the service will produce a very weak one at the burner head, in fact a mixture too weak to burn at all, and so put all possibility of lighting back out of court. The writer found that with a machine making a 6% gas (the same being diluted to the self-burning mixture at the burner head) upon shutting off the petrol supply and still allowing the machine to run, the lights soon became dim and in a short time the flame lifted right away from the mantle and went out. By the time that the failure of the petrol supply had reduced the gas in the service to the explosive point all danger of firing this was removed by the burners automatically going out. Even if by any mischance—and the writer cannot conceive one occurring in practice—the flame could be lighted at the nipple, the latter consisting of a comparatively heavy piece of metal of high thermal capacity, with a small hole in it from which the gas issues, acts in exactly the same way as a piece of gauze and extinguishes the flame by lowering its temperature.

It will be noticed that most—if not all—of the systems employing the low percentage gas are those in which some hand regulation of the mixture is provided for, *i.e.*, machines in which the gas is apt to vary. The fact of the provision of any mixture regulator is, in the author's opinion, an admission of the fact that the machine cannot be relied upon to keep delivering a gas always of the same "make." Now if the proportions of the mixture have to be regulated some index of the desired mixture has to be provided, and as the condition of a self-burning mixture is very strongly marked by the colour of the flame when burned without a mantle, a pilot jet can be fixed on the machine to give the necessary information. If a richer gas were made for the service this index would be of little or no use, as a gas rich in hydrocarbon burns with a yellow flame of very little variation of intensity over a fairly large range. Hence it is very convenient to burn a 2% mixture in a machine which cannot be relied upon to keep the same gas automatically.

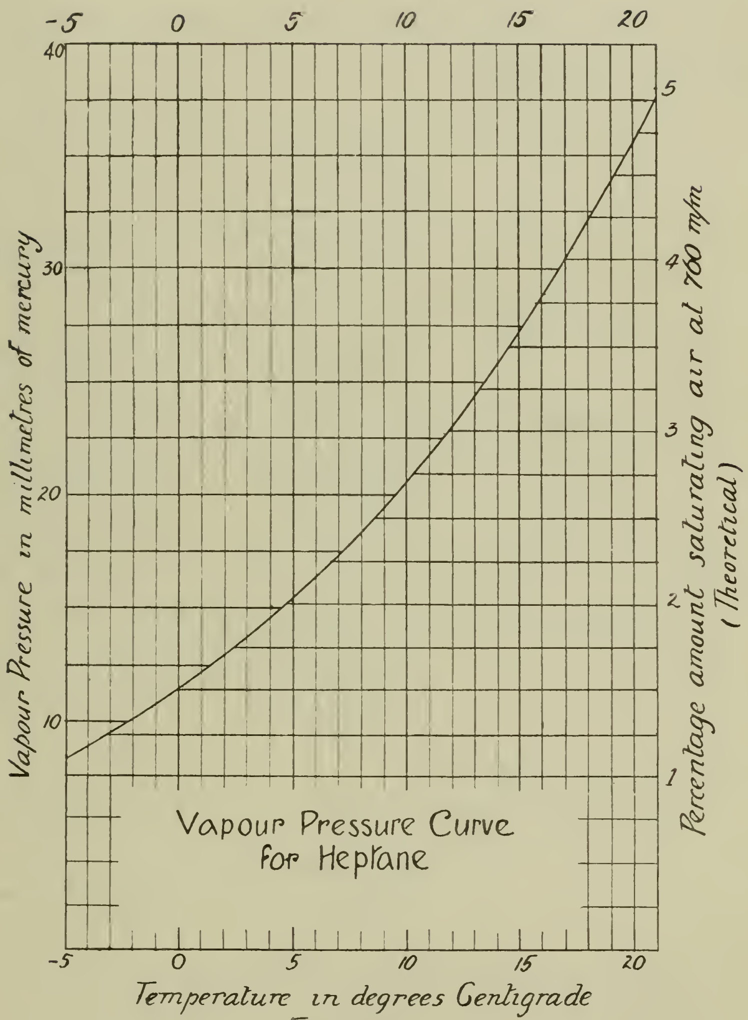

-5
0
5
10
15
20
40
30
20
10
Vapour Pressure in millimetres of mercury
5
4
3
2
1
Percentage amount saturating air at 760 m/m
(Theoretical)
Vapour Pressure Curve
for Heptane
-5
0
5
10
15
20
Temperature in degrees Centigrade

FIG 2

TABLE A.

FRACTIONAL DISTILLATION TESTS OF FUELS SHEWN ON FIG. 3.

M. Sorel's Experiments :—

				Deg. Cent.
A	contained fractions	50%	boiling below	67
		30%	between	67 and 89
		20%	above	89
B	contained fractions	40%	boiling below	71
		40%	between	71 and 96
		10%	between	96 and 106
		10%	above	106
C	contained fractions	20%	boiling below	70
		40%	between	70 and 101
		20%	between	101 and 123
		20%	above	123
D	contained fractions	20%	boiling below	72
		50%	between	72 and 101
		20%	between	101 and 127
		10%	above	127

Furnished by the Anglo-American Oil Co. :—

"Anglo-Special Spirit for Vapour Lamps and Gas Machines," sp. gr. 0·680, contained fractions—

56%	boiling below	71
37%	between	70 and 100
7%	above	99

Furnished by the Shell Co. :—

Shell "Swan" for Gas Making, sp. gr. ·680, contained fractions—

44%	boiling below	60
53%	between	60 and 80
3%	above	80

PURE HYDROCARBONS.

Pentane, sp. gr.	.. 0·626	boils at	37—39
Hexane ..	.. 0·663	,, ,,	69—71
Heptane ..	.. 0·688	,, ,,	98—100
Octane ..	.. 0·719	,, ,,	124
Nonane ..	.. 0·741	,, ,,	149

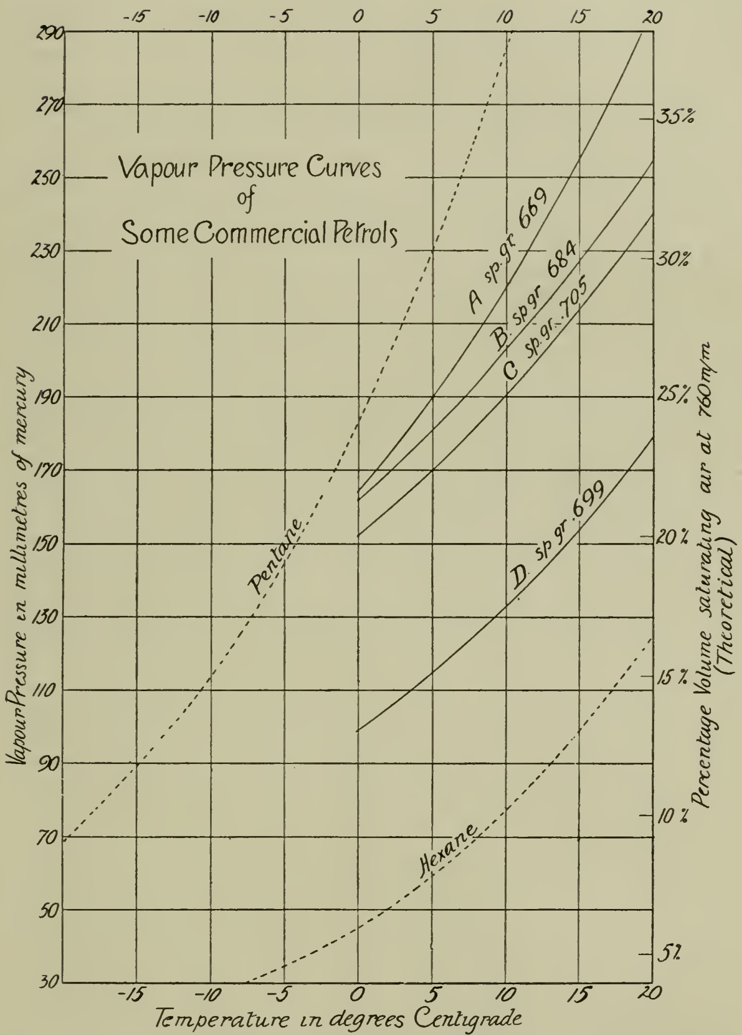

Vapour Pressure Curves
of
Some Commercial Petrols
A sp.gr. 669
B sp.gr. 684
C sp.gr. 705
D sp.gr. 699
Pentane
Hexane
Vapour Pressure in millimetres of mercury
Percentage Volume saturating air at 760m/m (Theoretical)
Temperature in degrees Centigrade
-15 -10 -5 0 5 10 15 20
290 270 250 230 210 190 170 150 130 110 90 70 50 30
35% 30% 25% 20% 15% 10% 5%

FIG. 3

A point which is little understood by the layman is the relative values from the pecuniary point of view of a gas which contains only 2% of vapour in its composition and a richer one containing say 6%. He is apt to imagine that he is getting more value for his money when his machine delivers 1,000 odd feet of gas to the gallon of petrol (since " air costs nothing") than if it only delivered 500 cubic feet. When petrol gas first came into prominence a great deal was made in advertisements of the low cost per 1,000 cubic feet compared with coal gas, so that an examination of the claim might not be out of place here.

From particulars kindly furnished by the Anglo-American Oil Co. the author gathers that each cubic foot of vapour from their " Anglo-Special 0·680 " requires for complete combustion 45·5 cubic feet of air, and a gallon gives 28·4 cubic feet of vapour. From this it will be seen that one can obtain 1,318 cubic feet of gas to the gallon of spirit and all for the comparatively small sum of 10d. Coal gas being sold in the country at an average price of about 3/6 per 1,000 ft., it is no wonder that gas managers began to wriggle when petrol gas first came on the scene. But the excessive cheapness was more apparent than real. The Anglo-American Oil Co. give the calorific value of this petrol at 19,500 to 20,000 B.T.U's per lb. or taking the lower figure 132,000 B.T.U's per gallon. Hence the calorific value of this gas, of which we get such a lot for 10d., is only just over 100 B.T.U's per cubic foot and gives a lighting value when burnt of little over 5 candles per foot. Coal gas has an average value of about 600 B.T.U's per cubic foot and gives a lighting value of 20 candles per cubic foot when burnt at low pressure with a mantle. Again, oil gas can be produced in the Mansfield apparatus at about 5s. per 1,000 cubic feet, an apparently high figure until one is acquainted with the fact that it has a calorific value of 1,200 B.T.U's and gives an efficiency of 40 to 50 candles per cubic foot. From the foregoing it is obvious that the figure simply of " so much a thousand " is utterly useless as an index of the cost of any gas.

The only valuable advantage in making a very weak gas is that an escape is immediately diluted down beyond the combustible limit by the air it meets in the room. But there is no excuse for having any escapes especially as—the specific gravity of the gas being over 1—little over half as much petrol gas as coal gas will escape through a given leak. No insurance company considers a coal gas installation a menace from the insurance point of view, so that in the author's opinion there is very little value in this point and certainly it is of no value as a set-off against a dangerous gas in the gasholder.

In the category of machines which rely upon hand regulation to keep the gas right the writer would include all machines using a " surface carburettor " in any shape or form, or machines

in which the fuel is allowed to run into the carburettor by gravity through a hole the proportions of which are governed by a needle which more or less chokes the aperture.

As there are several machines of the surface carburettor type on the market it might be as well perhaps to define the term. By a surface carburettor the author means one in which excess petrol is supplied by any float feed or similar device and air is allowed to pass over it picking up as much hydrocarbon as it can hold in the form of vapour. Sometimes this is passed straight on into the service and forms a very rich mixture which is burned at Bunsen burners or else it is diluted down to the self-burning mixture by some hand-regulated device (with which is usually arranged some attempt at an automatic control). Neither of these systems is, in the writer's opinion, satisfactory, as the amount of vapour which air will hold is governed by so many variable factors (time of contact, temperature, humidity and worst of all selective evaporation, a factor which it is practically impossible to control). In the case of the petrol feed through a hole choked by a needle the alterations of viscosity of the fuel have to be reckoned with, and where the needle is controlled by the height of a relief valve—when lights are reduced in number the gasholder raises the air exhaust valve and closes down the petrol supply by means of the needle—an adjustment is only reliable for a given speed of the engine.

There is another class of machine which uses a weak mixture because by so doing the latent heat of evaporation can be obtained from the air absorbing the vapour and hence no heat has to be supplied from an outside source. If no heat is supplied other than that derived from the specific heat of the air and the liquid, a drop in temperature will result of about 28° C. and, unless the air is supplied at several degrees above zero, the temperature will drop below the saturation temperature of a self-burning mixture, and the air will not hold even the 2% of vapour necessary for such a mixture. A machine built upon these lines, therefore, must be doubtful in frosty weather, and anyhow the air has to passed through some drying agent in order to take out all moisture before it reaches the carburettor, or the latter will soon choke up with snow and ice.

One of the first essential considerations in the design of a petrol gas plant is that of the motive power to be used to drive the apparatus. In order that the drop in pressure due to the passage of the gas through the pipes may be, for practical purposes, negligible compared to the pressure at which the gas enters the mains (and that the pressure at each point should be sufficient in the case of a rich gas to enable it to inject the extra air necessary for complete combustion, or in the case of a mixture already of self-burning proportions to force it through the layers of gauze, etc. used to prevent flashing back) it is found in practice

necessary to deliver the gas from the machine at between 1 in. and 2 in. of water column. Now a 40 c.p. unit may require a consumption in the case of a 6% gas of as much as 4 cubic feet an hour, or in the case of a self-burning mixture of 11 ft. an hour. The author is aware that these figures may be criticised by makers of petrol gas plant, so he would state at the outset that they are based upon experiments in a laboratory with machines of both types under ordinary running conditions. Now a pressure of 1 in. of water column is equivalent to 5·2 lb. per square foot, hence the energy required for a 40 c.p. unit consuming 4 ft. an hour at $1\frac{1}{2}$ in. is $1 \cdot 5 \times 5 \cdot 2 \times 4 = 31 \cdot 2$ ft. lbs. and with a weak gas consuming 11 ft. an hour $1 \cdot 5 \times 5 \cdot 2 \times 11 = 85 \cdot 8$ ft. lb., which reveals another advantage of the richer gas. Taking as a typical example a house in which there may be 50 lights all on at once, it will be seen that in one case an expenditure of 1560 ft. lb. is required and in the other 4290 ft. lb. for every hour's run. Hence petrol gas machines seldom require to be driven by anything more powerful than a hot-air motor or wound-up weights. In the author's opinion the latter method is the more satisfactory of the two, for in a well designed weight-driven apparatus the power expended is always proportional to the load from all lights on down to a small by-pass, and should all lights be turned out no power is wasted—the power coming into operation again immediately a light is turned on. In the case of an engine-driven plant it is necessary to run the engine continuously whatever the load and should it be thought necessary to provide for an emergency during the night when in the ordinary way no light would be required, either the engine must be kept running with no load. or a gasholder must be introduced supplementary to the rest of the plant. With a consumption of 11 cubic feet per light per hour it will be seen that the storage of any useful amount is out of the question.

The foregoing figures of the power required are purely theoretical, and as it is practically impossible to obtain an efficiency of more than 50% they should be at least doubled to obtain working figures. The writer unfortunately has no figures as to the efficiency of an engine-driven plant, but found that in one particular case the cost of running the engine of a 25-light plant the whole night on no load came to about 3d.

As one is continually being asked for comparisons with coal gas the following information should be of value. It may be stated at once that such comparisons are never satisfactory to both parties concerned as there is the inevitable difference of opinion as to what is the average efficiency which may fairly be assumed in each case. The difficulties of such comparisons will be obvious when it is pointed out that, according to how coal gas is burned, the duty obtainable from an incandescent

mantle may vary from as low as 11 candles per foot to as high as 40 candles a foot or more, though the latter is only possible with special compressing apparatus. The writer was present at some photometric tests made by Messrs. Mansfield & Co., Ltd. (the well-known oil gas firm) with two different types of petrol gas apparatus. They were tested just as sent out by the makers, and as presumably they would be installed in a private house; that is to say no special attempt was made to tune them up for the occasion, and the tests may consequently be considered as being made under quite average conditions. With rich petrol gas of 334 B.T.U.'s per cub. ft. gross a duty of 11·6 candles per cub. ft. per hour was obtained (or to be exact a 35 candle-power unit consumed 3 cub. ft. an hour). Now with petrol of ·680 sp. gr. and calorific value of 19,500 B.T.U.'s per lb. we get a value of 132,600 B.T.U.'s for 10d. net (which is about the present price of spirit after rebate of the tax to the consumer) from which data it is easily calculated that we get 1,000 candle-power hours for 2·17d. Assuming an efficiency for coal gas of 20 candles per cubic foot (and the writer considers this a very fair average for low-pressure house lighting), with gas at 3s. per 1,000 cubic feet (again a fair figure) we get 1,000 candle-power hours for 1·8d. Hence, light for light, petrol gas in this particular case was equivalent to coal gas at $\frac{2\cdot17}{1\cdot8} \times 3s. = 3s. 7\frac{1}{2}d$ per 1,000 cubic feet. It is interesting to note in support of the contention that these are fair comparisons that Professor Vivian Lewes, in the 10th edition of the Encyclopædia Brittanica, vol. 31, p. 653, gives the price of 1,000 candle hours with coal gas at 3s. as 2¼d. and with petrol at 10d. per gallon as 2d.

Any attempt at competition with coal gas is very much handicapped in the case of petrol gas by the consideration of the initial cost of the plant. In view of the very large field outside the radius of any central coal gas or electric lighting scheme one would not expect makers of petrol gas plant to spend time and money on such competition. Their chief rivals are acetylene firms and makers of private electric lighting plants. It is interesting to note that from figures given in a pamphlet issued by one of the best known acetylene firms the price per 1,000 candle-power hours from acetylene works out at 6·25d.; or, light for light, three times the cost of petrol gas. The author has no reliable figures for the cost of light generated by a self-contained electric set, but the initial cost of a sound apparatus is very heavy compared with that of a petrol gas plant, whilst there is the disadvantage of not being able to use it for the ordinary domestic purposes of cooking and heating except at a ruinous figure.

This paper refers exclusively to the principles of petrol air-gas lighting and no detailed examination has been made of the

different methods of its generation. It should be realised, however, that the design and construction of a machine are factors quite as important as is the fulfilment of the considerations here dealt with.

The difficulties in the path of the designer will be realised when it is pointed out that in an ideal plant a gas of unvarying calorific value and unvarying pressure has to be produced automatically to meet a demand varying from full load down to a mere by-pass under conditions of temperature varying within quite wide limits, and that this has to be effected with a fuel which, in its physical relationship to air, is peculiarly sensitive to these same ever changing factors of velocity and temperature. Moreover it must be remembered that the apparatus must be such that it can be left in the hands of any unskilled person such as a domestic servant or a gardener, and must therefore be "fool-proof" and never need attention other than that involved in ordinary routine work. Worst of all, a gas can be obtained by anyone by blowing air across petroleum spirit on its way to a burner with the consequence that all manner of unscientific persons are tempted into the field, the only result of whose labours is the loss of money and the "queering of the pitch" for firms running machines of sound construction and design which are necessarily the result of prolonged study and investigation. Is it any wonder then that the history of petrol air gas is strewn with the corpses of unsuccessful undertakings?

It is to be hoped that purchasers will gradually realise the folly of believing all that they are told about petrol air-gas machines and that they may be induced to obtain the services of an engineer to help them in the important choice of a reliable system, for this is the surest way of escaping the disappointment of finding themselves saddled with an installation which will cause them perpetual worry. There is no more satisfactory illuminant than that supplied by a good petrol gas plant, but there is no greater source of irritation than the constant blackening or dimming of mantles and the necessity for frequent readjustments of the machine, as in the case of some systems at present on the market.

Discussion.

The **President,** in moving a vote of thanks to the author, said that he thought the author was to be congratulated upon the manner in which he had dealt with the subject brought forward that evening. The paper had been a practical one from the expert's point of view, and it would doubtless prove to be of interest to consumers or intending consumers of petrol gas, since the author had very wisely stated certain drawbacks which might obtain and which had to be taken into consideration. Three points would appear to call for more particular attention, namely,

safety (which, of course, was very essential), reliability, and economy. The author had touched upon all of these points as far as the length of the paper would admit of his doing so, but he (the speaker) hoped that those points would come out into greater prominence during the discussion.

The vote of thanks was accorded by acclamation.

The **Secretary** read the following communications :—

Mr. R. W. A. Brewer wrote :—

"Mr. Scott-Snell has chosen for his paper a subject which is, I believe, original and which carries a great deal of interest, particularly as the oil industry is becoming daily more important. Up to the present practically all artificial illumination on a large scale has been derived from coal as the source of energy.

"This is true whether we consider electricity or gas as the final agent, with the exception that in the latter case a certain amount of oil is used for gas enriching. For the small consumer of light, however, paraffin oil has been in the past practically the sole illuminant, but even this is now being very largely displaced, particularly in small towns and working-class communities, by electricity on the slot-meter system. The oil companies are feeling very keenly the competition of the electricity supply corporations in this respect, and the consumption of paraffin for domestic purposes has fallen and is still falling rapidly on this account. The reason is not far to seek, for it is obvious that where a person, even of the poorer class, can obtain light and extinguish it with equal facility by operating a switch, he will do so in preference to undertaking the more inconvenient operation of striking matches and lighting a smelly lamp. Furthermore, the repeated cleaning and trimming which a lamp requires militates against its use.

"One cannot expect, therefore, that any other scheme of lighting can compete with electricity where slot-meters are employed or power can be obtained conveniently and cheaply, so that in considering petrol air-gas we must also consider the possible uses to which it can be put and its field of usefulness. The author of the paper concludes, and wisely so, that the principal competitors with his system are small private electrical and acetylene installations. Now, considering the first of these we have to face the fact that the introduction of metal filament lamps which can be conveniently installed on a 25 volt system, and which effect such a large saving in energy as compared with carbon filament lamps, has reduced the initial cost of an electric installation by at least 50%.

"This, of course, is due to the smaller number of storage batteries required and to the smaller size of the engine and dynamo, and whereas a 4 or 5 h.p. gas or oil engine was needed under the high voltage system, a plant of about 2 h.p. now suffices. Then, again, with regard to the cost of the installation

of the two systems, supposing every facility be given for running the wires or the pipes, we may take it that the piping of the air-gas system costs roughly one-half the wiring of the electrical system, and the noiseless working of the air-gas system is a point in its favour. As far as reliability is concerned, there is probably not much to choose between the two, and the cost of mantles and lamps will be about equal. Mr. Scott-Snell gives figures which show that, as far as an acetylene installation is concerned, the working cost is about three times that of petrol air-gas, but it is difficult to obtain a figure for a small electricity installation, as this depends on local conditions and the fuel employed. Petrol air-gas scores in its adaptability for domestic purposes, such as cooking and heating, and this should be carefully considered by anyone contemplating a lighting system for country house work.

"With regard to the plant itself, I can quite appreciate the difficulties which have to be surmounted in order that the gas delivered should be uniform in composition under all conditions of demand, air temperature, and humidity. These difficulties present themselves in many forms, yet, in spite of them, the great facility with which one can obtain some sort of a gas from petrol has caused persons to enter the field of petrol air-gas production with apparatus which either does not overcome many of the difficulties encountered in producing a correctly proportioned gas, or which makes complicated attempts at so doing.

"An examination of Mr. Scott-Snell's very able paper shows how very complicated the whole question is, particularly on account of the complex nature of the fuel dealt with. The author makes a particular point of running the system on a rich mixture, i.e., between 6 and 10% vapour, and I believe I am right in stating that these proportions are of the order of those used in his apparatus. I quite agree with him that the richest possible mixture within certain limits of temperature should be employed in systems of this kind, firstly, on the score of immunity from explosion in the apparatus itself; secondly, because with mixtures of such strength the flame will not travel back along the pipes; and, thirdly, because the pipes themselves need not be so large as in cases where, say, a 2% mixture is used, as then the whole of the air as well as the gas has to be carried down the pipe.

"There are two points of view from which one can consider the question of safety, the first being with regard to the apparatus itself, and I have already stated that with a rich mixture in use explosions are out of the question. Looked at from another standpoint, however, it may be argued that a leakage of rich gas into a room might produce an explosive mixture in that room, whereas with a 2% mixture such a thing is impossible. I do not think, however, that a 6% mixture would leak for a sufficient

time to produce an explosive mixture in a room, as it is evident that in order to do so the leak would have to be very considerable or long continuing.

"With regard to the main part of the paper, that dealing with vapour pressures, I think that the author has explained in a very clear manner the laws of evaporation based upon Dalton's experiments.

"With regard to the carburetting process, if one refers to page 138 of Sorel's book on 'Alcohol Engines,' one finds there an interesting table of vapour pressures, which indicates a considerable difference in the behaviour of a few hydrocarbon fuels at different temperatures. I will take the liberty of giving one or two figures for fuels at normal temperature, i.e., 15 deg. Centigrade :—

						mm.
Hexane ..	Vapour pressure	in mm.	of	mercury	=	95
Automobiline	,,	,,	,,	,,	=	154
Stelline	,,	,,	,,	,,	=	255
Moto-Naphtha	,,	,,	,,	,,	=	214
Benzo-Moteur	,,	,,	,,	,,	=	228
Kerosene	,,	,,	,,	,,	=	22
Benzol	,,	,,	,,	,,	=	61
Iso-pentane	,,	,,	,,	,,	=	475
Automobiline (first 10th)	,,	,,	,,	,,	=	336
Stelline (ninth 10th)	,,	,,	,,	,,	=	63

"Sorel states that, as far as vapour pressure is concerned, most of the fuels he examined lay between iso-pentane and hexane, viz., their pressure depended mainly on that of the most volatile constituent, even though these represent but a small fraction of the total mass ; selective evaporation must consequently be expected.

"To my mind, one of the most difficult features to contend with is selective evaporation, and the satisfactory working of any particular plant will be in no small measure due to the manner in which the air is allowed to take up the hydrocarbon vapour. I am firmly convinced that whenever a body of liquid is present in an air current, whether wicks are used or not, selective evaporation does take place, the heavier particles give way to the lighter, and the mass of liquid below the wick eventually consists of the less volatile fractions only. If the liquid hydrocarbon could be contained in a multitude of small cells in such a manner that each cell was separated from its neighbour by a medium impervious to the petrol, selective evaporation would not be of any consequence, as it would be necessary for the whole of the constituents of each particular cell to become evaporated before the next cell was exposed to the air.

"Some such end may be achieved by the use of a solidification process, and I have witnessed some interesting experiments in lighting with so-called solidified petrol. During these demonstrations selective evaporation apparently did not take place to any great extent, but I am not prepared to state a definite opinion one way or the other until more careful tests have been made. It appears to me that an important step could be made by the utilisation of spirit of greater density and less volatility than the special spirits such as the Swan brand, which are, I believe, largely used to-day.

"Naturally, one sees that the elimination of any external source of heat to supply the latent heat of evaporation of the liquid, is an advantage as far as simplicity is concerned. There is, however, of necessity another difficulty encountered when external heating is applied, namely, that due to an irregular demand made upon a machine, and the consequent variation in the rate of flow of liquid through the carburetting appliance. In conclusion, one can only make a compromise, and sometimes sacrifice, say, a small additional expenditure in the fuel for the sake of the simplicity of the necessary carburetting apparatus. In many similar instances this is sometimes lost sight of, and in order to gain a very small amount in efficiency of working, a very great deal is really lost by way of added complications to the mechanism and increase in risk of breakdown resulting therefrom.

"I cannot say that the author's apparatus would be classified as a complicated one, as its working details are simplicity itself, and the mechanism which operates the gasholder, whilst apparently tricky, is really a fine piece of work and reflects great credit upon him."

Mr. Fred. Dye wrote :—

"The paper shows a deep technical knowledge of the subject, and there is abundant evidence of practical experience, which makes the paper doubly valuable.

"One obvious outcome of this practical knowledge is the championing of the 'rich' gas, for while the 2% gas is given perfectly fair treatment, the true advantages of the richer mixture are, I believe, for the first time publicly spoken of. The 2% people have been condemning the rich mixture so persistently and so widely as to make the public positively afraid of a rich gas, yet anyone having real experience of the latter soon finds that it is far more safe than appears possible, and certainly much safer than coal gas.

"What criticism I have to offer amounts only to saying that the rich mixture has not had all its real advantages set forth. The first omission is that the fact that rich gas will store well has not been dwelt upon fully. I need not say that when cost will admit it is really much better to take gas from a storage holder

than to rely on having it only when the machine is running. A railway station recently lighted has the gas made twice a week, during day hours, and this serves seven nights per week, during which time the gas shows no appreciable deterioration. Reflection and experience show that if gas can be stored and used from the store, it is a great advantage. It is only the cost of the holder that stands in the way, and for important works the cost of this is not considered a bar.

"The next thing is the omission to mention how advantageous the rich mixture is in being suitable for working with ordinary commercial gas-burning appliances other than lighting burners. The well-known firm of John Wright & Co. have supplied me with cookers, gas steam radiators, boiling rings, soldering iron stoves, gas boilers, urns, and other appliances, all of their ordinary design and make as used with coal gas, the only alteration being a moderate enlargement of the gas nipples in the burners (to pass more gas) and the provision of well-fitting adjustable air collars to the air chambers. The rich gas burns quite well at the ordinary plain openings of the burners, not requiring gauze or any special provision.

"The latter matter seems to me to be most important, as I believe many orders have been, and will be, secured, or certainly influenced, by a knowledge that petrol gas can be used for all the ordinary domestic or industrial purposes that coal gas is put to, at about the same cost, with the same appliances. It is an important factor in making petrol gas popular.

"I may add that I have just fitted a large apparatus solely for heating soldering irons in a factory where tin cans are wanted in large numbers. The workers say the irons heat better and cleaner than with charcoal stoves, and general satisfaction is expressed."

Professor C. A. M. Smith said that he might be permitted to say that to some slight extent he appreciated the difficulties of the problem which the author had set himself in preparing a paper upon the subject of petrol air-gas, because, nearly a year ago, he was requested to give a popular lecture, and as at the time he had to look into the question of lighting a fairly large house in the country, he was led to investigate the question of petrol air-gas. The difficulty with which he was met was very similar to the difficulty met with by others when they were asked to deal with the matter, and he was very doubtful about what to recommend until he had actually gone into the thing very thoroughly and tried certain of the clever devices which were in existence.

The great thing which struck him at once when he first went into the subject was the almost entire absence of scientific literature upon it. There were pamphlets issued by various makers. The writers of these pamphlets certainly should have gone in for

journalism as a profession. It seemed to him that the time had arrived when what was really needed was protection for those people who were doing good work. The worst of the business was that anyone could cause petrol to give a light with an incandescent mantle, consequently a lot of people rushed into the business, and it seemed to him that some society, such as the Society of Engineers or the Society of Arts, should take up the subject, and say definitely what the plants were capable of doing. It would not be at all a bad idea if such a society invited various makers to enter into competition in the same way as had been done in other instances, as, for example, suction gas plants. Of course, the people who did not get medals would not like it, but that fact had to be faced.

The author of the paper, of course, was a practical maker of plant, and he had written a paper in which he approached the subject from a theoretical point of view. He should not altogether like the job of abstracting the paper. In places it was very hard indeed to digest, and it needed very careful thought. That was because the author had tackled the whole thing from a theoretical point of view. He (the speaker) had in his work to talk theory, and he found it very difficult to drive home such complicated things.

The author had not said very much upon the point of how petrol air-gas plants worked. It was just possible that there were people present who did not quite understand how a plant actually did work. He had put upon the wall some diagrams showing the old type of plant. There had to be a form of power delivered to the plant to drive it. The chief thing was to force the gas through the pipes when it was made. A very old German type was shown on one of the diagrams. It must be thoroughly understood that with these machines it was a question of evolution. In the old type shown there was a pulley driven by a belt, and that turned round a thing which might almost be said to be a screw. The petrol was placed in the tank shown, and, of course, air passed over that petrol, and took up an indefinite amount of petrol vapour—there was no very close regulation or anything of that sort—and the air and the petrol vapour were forced along by the rotating drum or screw to another chamber. Some of the petrol, of course, dropped down, and the air and petrol gas passed along.

That was quite an elementary sort of thing. There were absolutely no difficulties to overcome in that plant; it all operated quite simply, and one might therefore think that such plants were simple, but, unfortunately, there were one or two points in which that was not the case. The modern plants fulfilled very difficult conditions, which he would elaborate. One had to be rather careful in discussing the paper because the name of Mr. Scott-Snell was not quite unknown in the technical press;

he was a vigorous critic, and he (the speaker) did not want to enter into a very arduous correspondence. But at the same time it seemed to him that the author had gone into the whole thing, and had come out as a kind of champion of the 6% mixture. One thing the author touched upon was the question of the gain by the reduction of motive power for the 6% type of apparatus. Mr. Scott-Snell also spoke of the fallacy of advertisements which told of the advantage of a plant because it produced so many thousand cubic feet of gas. The petrol air-gas people were not the only sinners in that direction. The coal gas industry had given a very bad lead. They had not been sufficiently scientific, and he would even go so far as to say that he did not think that they were sufficiently scientific at the present time. For example, a colleague of his at the East London College, Professor Morris, made some tests to compare coal gas with electric light, and he had found that he could get in one part of London a maximum candle power with a lamp of 800 candles, but when he took the same lamp to another part of the city which had different coal gas supplied by a different company, he found that with the same lamp he would get 1,250 candle power, and he stated that it was highly probable that if he went up to Edinburgh he would have 1,500 candle power. The great trouble was that the consumer did not appreciate, when he was getting coal gas, say, at 2s. a thousand, that he might get a better article in another part of London or in another part of the country if he paid half a crown. In fact, it seemed to him that coal gas should be sold by the thermal unit or by the calorific power.

With regard to the question of the conditions of a plant, he sent to all the makers he knew a circular letter stating that he wanted full information upon the matter, and saying that he would give them every opportunity to exhibit their plants running at the East London College where he was giving the lectures. Three makers responded. There was a very sharp contrast between the way in which they dealt with the matter. Very few of the firms had men with any engineering or scientific qualifications. Petrol air-gas plants required designers who were well trained in science. In that respect he had to congratulate both Mr. Scott-Snell and his partner, as they both fully understood the technicalities of the problem before them. He considered that it was a most excellent thing that every plant should be tested before it came away from the works, and that a complete record of the tests should be kept.

What were the conditions which they desired the plants to meet? First of all, quite obviously, when a plant went away to a country house, and the gardener had to look after it, it must have simplicity. The difficulty was that the plant had to be effective under varying atmospheric conditions. There were

different conditions in the height of summer and the middle of winter. Another great problem was that the plant had to be such that it should be absolutely at the top note whatever number of lights was burning. If a house had 100 lights the plant must do quite as well when there were 100 lights burning as when only one light was burning. The maid must be able to go into a room and turn on a light without any trouble. To obtain such a result was not so easy as it seemed.

Another thing was that there must be silent running. People did not want to have a noise. For that reason weight-driven plants were desirable for private houses. If a village was to be supplied with light power by petrol air-gas it would probably be well to have a central station from which to distribute the petrol air-gas. If the whole thing was big enough there might be a man in charge.

With regard to the question of the 6% mixture, it had been made to some extent the most prominent point of the paper. He thought when he first went into the matter that there was not very much in the question of 6%, and that there might be explosions if the gas leaked into the air as with coal gas. He really did not, on reflection, think that there would be any trouble in that direction, but what burdened him was the question of what happened when there was a weaker mixture for the gas. Where there had to be adjustment of the burner the plant was absolutely hopeless. There must be a plant that would burn without gauze at the burner. But all of the 1½ to 2% mixture plants used gauze. Anyone who had experience of incandescent gas lighting knew the great trouble which arose if there was gauze, and if there was dust collecting, and so on. If the gauze was not there the light might flash back along the pipes and wreck the plant. When he (the speaker) published a resumé of his lectures, Mr. Brewer rather took him to task because he did not give preference to the 6% mixture. He thought that Mr. Brewer was quite under a wrong impression. He (the speaker) agreed with every word which had been said by Mr. Brewer in the communication which had been read about the 6% mixture.

There was one curious thing about petrol air-gas, namely, that for some reason or other—it was probably because the temperature of the flame was much higher—more illuminating power per thermal unit was obtained than was got from coal gas. That was a point which was worth noting.

The author, towards the end of the paper, went very fully into the difficulty in the mind of the layman. It was most unfortunate that the coal gas people had set up the standard in the ordinary man's mind that if he bought so many feet of gas that was what he was buying. It was not the case at all. What was being bought was so many thermal units. That was the proper way of looking at the thing.

Towards the end of the paper the author said : " It should be realised, however, that the design and construction of a machine are factors quite as important as is the fulfilment of the considerations here dealt with." As a matter of fact, of course, the design was what people bought. People were looking for the best machine.

What the author had succeeded in doing was very admirable indeed. He had introduced a method by means of which he delivered automatically the same mixture per stroke, however many lamps were put on. He had adopted a plunger pump for the petrol supply. Simultaneously with the pump there was operated a sort of air pump. Thus the machine pushed a certain definite amount of petrol and a certain definite amount of air, as the demand came. The inventor of it was quite scientific ; unlike many other inventors in the same field, he did not trust to luck. His machine was a sound engineering job.

There was another plant which he had seen which made an attempt in the same direction, and was, he thought, very admirable, but he was not quite so sure that exactly the same quantity of petrol was picked up per stroke.

The author said : " Worst of all, a gas can be obtained by anyone by blowing across petroleum spirit on its way to a burner, with the consequence that all manner of unscientific persons are tempted into the field." Both he (the speaker) and his assistant, when they were dealing with the question, had the greatest difficulty in keeping away from the Patent Office. The problem was a most interesting engineering one. He, having done some experimental work in connection with the matter, strongly advised anyone to leave the subject alone unless he had a great deal of spare time. Probably, as the author had said, the only thing that would result would be the " queering of the pitch " for other people. That petrol air-gas had a big future he had not the slightest doubt. On the Continent it had gone ahead very much more than it had in this country.

With reference to what was said in the last paragraph of the paper, people spent a good deal of money in consulting a solicitor or any other professional man, but they thought that they could do their own engineering work for themselves. Everybody knew the old lawyer's toast, " Here's to the man who makes his own will." He thought that undertakers ought to toast the people who did their own engineering work. He always told a medical friend of his, " Theie is one great difference between you and engineers. If you make a mistake you bury your mistake, but if we engineers make a mistake it buries us." He would strongly urge those who were going to buy petrol gas plants to consult an engineer. Many of the plants had been failures. The matter could not be taken up in an amateur fashion. He had seen many excellent appliances, but he was sure that it was a very

difficult thing to get a plant which would run satisfactorily and fulfil the numerous conditions to which he had alluded. To accomplish that end the inventor must possess the scientific and engineering instinct, and have had great experience in the work. Fortunately, those who knew Mr. Scott-Snell had the utmost confidence that he fully understood the problems connected with petrol air-gas.

Dr. Samuel Rideal said that the problem involved in the paper was an engineering one and not a chemical one. It was perfectly well known that a certain mixture of petrol and air burnt, and that a certain mixture of petrol and air exploded. One needed to get the right mixture for burning in order that it might be a satisfactory illuminant, and, having got that mixture, one had to keep it. The difficulty of keeping it depended upon the facts that the mixture was not a perfect mixture, and that the petrol had a tendency to condense out and separate, and also upon the fact, which was overlooked in the construction of a good many plants, that the atmospheric pressure varied from day to day and from minute to minute, and that, therefore, the original mixture obtained by any method of carburation which might be devised was only true for a particular temperature and a particular pressure. Therefore, in his opinion, the perfect plant had yet to be invented by the engineer. Whether an automatic barometric recording carburating air-gas plant would be produced by the engineer or not it was out of his province to say. Some years ago he investigated one of the plants which had been bought on the faith of some of the literature referred to by Professor Smith. The plant was said to be capable of being worked by any servant. The servants were produced in court; a cook, a gardener, and, he thought, a coachman, who all said that the plant could be worked by them. He (Dr. Rideal) was called, and he said that he could work the plant, although he had never seen it before, in a few minutes. But there was another cook who was produced on the other side, who said that she could not do it. The judge dismissed his (Dr. Rideal's) evidence as having no bearing on the case, but as there was the positive fact that one cook had not been able to work it, he had to find against the makers of the plant.

It was really a very difficult matter for people living in the country as he did to get even an electrical plant to work satisfactorily. He had at the present time an electrical plant which was not fulfilling its duties in the way it should fulfil them. But when one came to air-gas plants it was found that such plants had a trick of going wrong. They went wrong, he believed, through the two causes he had just mentioned, namely, variations in temperature and variations in barometric pressure. The problem was one of such complexity that he did not quite see how it was going to be solved. It was a difficult problem

to ensure a petrol of any definite specific gravity. Even if one could be sure that all the cans of petrol used in the air-gas plant had the same gravity to the third place of decimals, and even if one could control the atmospheric conditions, the petrol left in the carburettor was continually altering in gravity and getting less easily volatilised, and, therefore, the pump which was pumping the air through the petrol was removing smaller quantities of petrol per unit of time. As the petrol was evaporated from any tin of petrol its density varied from moment to moment, and, therefore, one never got the same mixture for more than a second at a time. There was no carburettor which would drive a uniform mixture of air and petrol unless the petrol itself was of one chemical substance and one gravity. All the petrols were made by distilling crude paraffin, by which there was obtained a fraction which was supposed to boil at a particular boiling point ; but when one went into the matter more minutely it was found that it consisted of a whole series—hextane, heptane, and so on—so that it was not possible to get a petrol of uniform composition, and, therefore, the mixture was of varying composition. The humidity of the air was another factor which was of importance, and when the outside air was below freezing point another set of conditions were introduced. It was very difficult indeed, in his opinion, to produce a plant which would work constantly, uniformly, and satisfactorily under all conditions.

He was aware that a large number of petrol air-gas plants were going to the tropics. He recently came home from Malay and India, and he was surprised to find how many plants were going out to these very hot countries. A plant which would work automatically and perfectly in the works might not work satisfactorily under these tropical conditions. Although he agreed with what had been said about the desirability of plants being tested in the works before being sent to the customers, it seemed to him that a plant which would work well in England was not at all likely to work well, for instance, in India, where it was very difficult to keep petrol in a tin at all.

Mr. W. A. Tookey said that he thought that this was the first paper read before an engineering society which had dealt at any length with the subject of vapour pressures in connection with petrol air-gas apparatus. Vapour pressures and the relation of the limit of saturation of air with petrol gas at various temperatures to the explosibility of such mixtures were matters which many makers of petrol air-gas plants had, he thought, entirely overlooked. The exposition of this subject was a most important feature in the paper.

With regard to surface carburettors as defined in the paper, he was entirely in agreement with the author. They were very

difficult indeed to control. They permitted a very variable "make" of gas, and frequently, on account of the many ways in which the carburation could be affected, references to which had already been made, it happened that the gas, when used in a stove either for heating or for cooking, would light anywhere but at the burners.

There was a great deal to be said for definitely measuring the volume of petrol and proportioning it to a measured volume of air. It was not a difficult thing to do. Of course, it was necessary to take into consideration all the conditions which obtained at the final destination of the apparatus, and especially as regards climatic temperatures and effect of altitude. He was of the opinion that all such apparatus should have some system of measurement, as no reliance could be placed upon the haphazard results obtained from surface carburettors.

He was glad to see that in the paper there had been some attempt to put the relative advantages of town gas and petrol gas in a definite statement. It had been claimed that petrol gas was advantageous even for factories which had town gas mains outside the doors, and he thought that the author had done a very wise thing in emphasising the advantages of town gas rather than supporting a claim for petrol air-gas which could not be borne out in practice except in rare instances.

Another point to which the author had directed attention was the competition of petrol air-gas with electric light. There was no doubt at all that petrol air-gas would be used very largely in this country, especially in country districts and for small-sized houses, but larger houses would use electric light. The electric light had decided advantages, and when the installation was sufficiently large to merit the increased cost of construction and erection, these advantages would outweigh the merits of petrol air-gas, even though the latter could be used for cooking and heating.

To his mind the one weak spot in a petrol air-gas system was the necessity of using incandescent mantles. The renewals of these amounted to a considerable sum in the course of a year even when the utmost care was observed by those responsible for the cleaning of globes and chimneys. Failing such care, breakages of mantles often resulted in the consequent breakage of globes, in the same irritating manner as with burners supplied with town gas.

Mr. M. Holroyd Smith regretted that the author had not given a description of some apparatus, either his own or those of some other people, which would produce the desired effect. He would have been keenly interested to see how the desired effect could be arrived at.

Mr. H. C. Robottom was very much obliged to the author for the valuable information he had given, but, like the last speaker, he would have been very pleased to have some practical demonstration.

The point which had been raised with regard to the percentage of petrol used in the mixture was, of course, a very important one. The author made no reference to any mixture except the 6% mixture and the 2% mixture and the 1½% mixture. He thought perhaps there was some knowledge to be gained with regard to mixtures with, perhaps, 3 or 4 %. At any rate, the matter was worthy of consideration.

Mr. John McV. Morris said that, like the two previous speakers, he should have liked to see some practical demonstration of the petrol air-gas machine showing the way in which the gas was produced.

Mr. C. P. Blatchley thought that there was one point which had not been altogether caught, and that was in a petrol gas machine one of two methods could be adopted. They could either sail very near all the practical conditions which governed the amount of petrol which could be satisfactorily evaporated and held in a given amount of air, or they could, perhaps at the expense of a little more money, steer clear of all possible chance of disaster.

Dr. Rideal had given a list of the various factors which affected the stability of petrol gas. They formed a very long and formidable list. Dr. Rideal began with the conditions of the barometer; he went on to the thermometer, and then spoke of the possibility of selective evaporation. He said further that they had also to consider the humidity of the air, and, finally, that, when they came to realise that there were all those different physical factors at work, they would see the impossibility of producing a gas which would be satisfactory. That was true only if one was making a gas the properties of which were in the neighbourhood of the points at which the gas would break down. Let them suppose, for instance, that they tried to make their gas from commercial petrol. There were one or two firms who tried to do so, but he knew of only one or two such firms. The majority did not do so, because they had found the folly of it. The reason for using commercial petrol was that commercial petrol was cheap. (The slight extra gain in thermal value was negligible.) Petrol of a specific gravity of 0·760 (i.e., commercial petrol) cost about 9d. a gallon, including the tax, whereas petrol of a specific gravity of 0·680, such as was used by most petrol gas manufacturers, cost 11½d. a gallon, that was 2½d. more. There were firms which attempted to use commercial petrol to save that 2½d., but the result of using it was that, first, they had to heat

their carburettors because it would not evaporate quickly enough (they said that they did so in order to supply the latent heat of evaporation; but with all due respect to them—having tested the matter practically himself—he would assert that it was in order to get the spirit to evaporate quickly enough). Second, they produced a gas which contained only 1·5 per cent. of petrol, so that it was close upon the point of maximum explosibility; and third, they produced a gas which was very easily made to drop its petrol by coming into a cold section of pipe. That was an example of making a gas which was near the limits of instability. Petrol gas was in any case so very cheap that the saving effected by using commercial petrol was, even in the case of very large installations, only about £1 per annum. Hence it was very bad policy for the sake of so small an economy to run the risks of an inefficient or even dangerous installation. By the use of the right spirit one could avoid the possibility of a deposit of petrol taking place in the pipes, and also one was able to make a 6% mixture which, as the author had demonstrated, could not explode, and they would get a gas of such a composition that it was quite independent of barometric pressure or humidity. The amount of vapour held in air was, of course, influenced by the barometric pressure, but it was only influenced by it when the air was saturated or nearly saturated. The barometer pressure would not affect the amount of vapour in the slightest when they were very far from the saturation point. They were also far from the point at which moisture in the air would affect it. In fact, working with the right petrol, they were nowhere near any of these critical points. As long as they did not attempt to effect small economies by using commercial petrol the gas was perfectly stable. He thought that this was a point which ought to be insisted upon, because the public was very easily gulled. As an example of the exaggerated claims sometimes made, one firm claimed that it produced 1,000 candle hours for 0·8 pence. The author had shown that the actual price was 2d. He (the speaker) had read a test by Professor Smith which came out at 2·3d. or 2·5 pence, and he had seen tests which had come out at 2·1d. Therefore all considerations showed that the claim that they produced 1,000 candle hours for 0·8d. was absurd, and was simply an exaggeration inserted for advertising purposes. The light was a cheap light in any case, and reliable firms would not attempt to magnify its obvious advantages, as they could more than hold their own on the plain merits of the light.

Mr. W. J. A. Butterfield said, with regard to the theory of carburetting, that much of what had been said by the author with regard to the vapour tensions of composite carburetting liquids was stated fifteen, twenty, or twenty-five years ago by gas engineers when they had before them the problem of carburetting gas with

hydro-carbon vapour in order to enrich it. The author had quoted figures of comparatively recent date in regard to vapour tensions, but as far as he could see he had passed over the old data based on careful experiments by Professor Bunte, Professor William Foster and many gas engineers, which data were crystallised in the text-books of gas manufacture in regard to the carburation of gas. He thought that it was a pity that the author had not added to his curves for vapour pressures the data which he would find in some of the literature of fifteen or twenty years ago on the carburetting of gas.

The author was clearly an advocate of the rich mixture. It had advantages, but, of course, if it did escape into a room it would, with a very little dilution, become explosive. It was not fair to say that it was comparable in that respect with coal gas, because coal gas did not become explosive until a very much larger quantity had escaped into a room. It might be more comparable with acetylene in that respect.

As far as he could judge from glancing through the paper, the author took it for granted that the lowest combustible mixture was explosive ; but the working of low proportion petrol air-gas plants showed that that was not the case. Time after time when he (Mr. Butterfield) had to inspect petrol air-gas plants with a view to advising clients which plant to adopt, he had seen low proportion petrol air-gas plants, and the makers had assured him that the mixture was not explosive and was not ordinarily combustible. In such cases he had said : "To assure me, just take off a burner and apply a flame," and, this being done, it was shown that the gas would not light except at a properly constructed burner, and it did not fire back.

With regard to the experiment of the author in which he took the richer gas and cut off the petrol until it was used up, in order to see whether, when the dilution of the gas with air reached a certain point, it would flash back and explode in the generator, it seemed to him that he should have tried that experiment without a burner. The explosive wave would not pass back through the nipple of a burner even if there were an explosive mixture in the generating plant.

Then with regard to one of the experiments which the author showed on the table, it was very much a question of stratification of the petrol vapour and the air. They must remember that the petrol vapour was about two and a half times as heavy as the air, and hence they could light the petrol and there would be no explosion, because the petrol vapour remained almost unmixed with the air on account of its higher density.

There was one interesting point which had been lightly touched upon by the author, and that was with regard to the comparative value of petrol air-gas and coal gas or town gas for heating purposes. As a matter of fact, the relation was strictly

in proportion to the calorific value of the town gas and of the petrol used in producing the petrol air-gas. Some time ago he investigated that point. A petrol air-gas company proposed to turn town gas out of a factory and to substitute air-gas. The owners of the factory, before adopting air-gas, thought it well to study the question. The gas was for industrial heating, and there was no question of lighting at all. He tried various mixtures of petrol air-gas, and the result was that all through, where he was able to get, say, 60% of the calorific power of the coal gas doing work, he was able to get 60 % of the calorific power of the petrol in the air-gas to do the same work of heating. The result of the enquiry was that he was able to say : " If you have coal gas of 600 British thermal units for heating purposes, costing half a crown a thousand cubic feet, your petrol must not cost you more than 7½d. per gallon if petrol air-gas is to prove as cheap as coal gas. That took account merely of the cost of the petrol without any allowance for the cost of converting it into air-gas.

He thought that in many respects the rich mixture which the author advocated was better than a poorer mixture, but in countries where there was a greater variation of temperature between night and day than in England, he certainly thought the rich mixture was more likely to be troublesome than poorer mixtures.

The author had quoted figures comparing petrol air-gas and acetylene for lighting purposes, and stated that the cost of the acetylene light was three times that of petrol gas. He (the speaker) imagined that in that case the author had taken the luminous flame acetylene burners, but if an upright incandescent burner was used the cost of lighting by acetylene was halved. Further, if the inverted burner which had come forward within the last twelve months was taken, the cost of acetylene lighting (even on the data in the paper, which he would not criticise) would be brought to practically the same as that of petrol lighting. He believed that, generally speaking, for heating as well as lighting purposes acetylene would be found to be more convenient. If one wished to dispense with the use of mantles altogether one could use acetylene without mantles, but petrol air-gas without mantles was a thing of the past.

Mr. Alexander Jackson, on being invited to speak, said that he had come to gain information, and he was afraid that he was unable to impart any ; but he thought that they had been well summoned if it was only to make the acquaintance of the cook mentioned by Dr. Rideal.

Mr. Arthur Valon said that he had come to the meeting not to speak but to listen, and, in the hope of hearing a justification of some of the elaborate advertisements with regard to petrol gas. In the paper there was the statement that the average price of coal gas was 3s. 6d. a thousand cubic feet. He did not know

where the author got that figure from, but he should say that the average price of coal gas throughout the country was under 3s. Perhaps the author's average was calculated by attaching the same importance to the thirteen thousand millions made by the South Metropolitan and sold at 2s. 2d. as to a small place selling, say, five millions at 6s.

He was primarily concerned with a gas other than that under discussion, but had, on occasions, been asked to advise with regard to the desirability of introducing petrol air-gas in cases where there was not a supply of coal gas available, or when the gas was at a very high price, but he had never found petrol air-gas a competitor, serious or otherwise, with coal gas when a decent supply of coal gas at a fairly reasonable price was to be had, even when it was considerably higher than 3s. 6d.

The author stated that the petrol gas in the particular case he mentioned was equivalent to coal gas at 3s. 7½d. That was only allowing for the cost of the petrol, but there was a great deal to be added to that. The plant had to be found and it had to be worked. Although there might be spare labour, the trouble cost something. The convenience of having only to turn on a tap was also worth something. He considered that 3s. 7½d. was rather low. As a matter of fact, it would pay to have coal gas at 4s. 6d.

With regard to Professor Smith's remarks, he seemed to think that the sale of gas by the thousand cubic feet was wrong and unscientific, and that the present state of things was all due to the unscientific rule-of-thumb methods of coal gas engineers, and apparently Professor Smith wanted gas sold by thermal units or by its calorific value. But Professor Smith would not be satisfied even with that, because what he objected to was that in one part there was coal-gas having one calorific value and in another part coal gas had another calorific value. What he wanted, apparently, was a uniform calorific value all over, in order that he might be able to get the same duty from a lamp in one place as he got in another. But for this, in addition to uniform calorific value, it would be necessary to have gas of uniform composition. But, besides being a scientific question, it was also a commercial one, for it might pay in one part of the country where a particular kind of coal could be obtained to make gas of one calorific value, while in another part of the country, where a different kind of coal could be best obtained it might pay better to make a lower quality gas. When he said "pay" he meant pay the consumer, because he might get his thermal units cheaper. He thought that Professor Smith was right to a certain extent. The tendency of the present time was for gas engineers to look upon the gas they supplied as being of so many British thermal units, and it was quite right that it should be so now, but the present state of things was the outcome of a long period during

which gas was sold for its illuminating power *per se*, and not for its heating value at all, and most undertakings were still subject to legislative enactments to the effect that gas companies should sell gas of a certain illuminating power *per se*. In London at the present time there was a definite minimum calorific value imposed. The calorific value, however, was not the only thing to be considered.

There was one other point, but it had really nothing whatever to do with petrol air-gas. In one of the written communications which had been read it was stated, as he understood it, that at the present time workmen were taking electricity by means of slot meters, but he should think that, for one workman who took electricity by means of a slot meter there were a thousand who took their gas in that way.

Mr. J. J. Rawlings said that the author dealt with the composition of the gas in the making. He (the speaker) understood that it was very materially affected by the humidity of the air in the first instance, and he understood that there were machines on the market that removed the moisture by a desiccating substance such as chloride of calcium, by which means the stability of the gas would be assured whatever the humidity might be, even up to the 6% of enrichment, and he should like to hear from the author that this was so.

Mr. C. Hoddle said that he would like to make a few remarks with regard to the comparative cost of petrol air-gas and acetylene ; as an acetylenist he had no reason to complain of the way in which petrol had been spoken of that evening regarding the many disadvantages connected with it.

The author quoted figures showing that acetylene cost 6d. per thousand candle power hours as compared with 2d. for petrol gas. He (the speaker) took it that the 2d. mentioned was to be spent entirely on petrol, as there was no mention of mantles or any of the other expenses which were necessary in the case of petrol.

There was one point which had not been mentioned in regard to petrol, but had been mentioned with regard to coal gas, and that was that there might be a variation of from 11 candles per foot to 40 candles per foot or more. He supposed that if that was so with coal gas it would also apply to petrol air-gas. He took it that the maximum of 11 candles per foot (for petrol air-gas) was with the rich mixtures and with the mantle at its best, but as the mantle deteriorated we should get down to a minimum of about two candles per foot, so the difference in cost as against acetylene was more apparent than real. It had been stated that petrol gas had a very great future, but he did not share that opinion ; only about three weeks ago his firm fitted up with

acetylene the house of a gentleman who had turned out three different makes of petrol plants. Even given a perfect plant, which he did not admit existed at the present time, petrol air-gas had no chance against acetylene.

Mr. L. E. Currey said that one thing which seemed to have been overlooked with regard to petrol air-gas was the quality of the light itself. This seemed to be superior to that of any other light which was at present on the market. He should like to know whether the plant mentioned in the paper was burning only at one burner or was burning at several burners, because the pressure would vary very considerably according to whether there were twenty-five lights going at once or only one or two. He believed that with most weak gas plants the pressure as measured on the water gauge increased as the lights were turned off; and, if that were so, naturally each burner would use more gas.

He did not believe that 11 cubic feet for a weak gas plant was correct for an average. He believed that it ranged somewhere between 6 and 9. Of course, that would make a very considerable difference in the price as quoted in the paper.

REPLY.

Mr. Scott-Snell, in reply, said that Mr. Butterfield had pointed out that the lowest combustible mixture was explosive, and that makers had assured him that it would not light except at a properly constructed burner, but that he had asked them to unscrew the burner and put the light to it, and then, to his amazement or satisfaction (according to what he was looking for) he had found that it blew the match out. He (the author) knew for a fact that it was simply a velocity question. In fact, the small experiment which he had made, where the velocity was very low, entirely gave the lie to that as a demonstration. It did light back if the velocity was not great enough. With regard to the statement that it would not light except at a properly constructed burner, he regarded that statement very much as a piece of advertisement "padding." It would burn whenever the velocity of efflux was equal to, or less than, the lighting back rate of the mixture.

The makers said that it had to be "atomised" before it could be combusted, but when there was a mixture of petrol and air going through a long length of main past angles and through different sizes of pipes, it was ridiculous to suppose that one did not get a perfect mixture until it had gone through a small bit of gauze. One did obtain a perfect mixture, and the "atomising" story was used to disguise the real purpose of the gauze, viz., to prevent lighting back into the service.

Replying to what Mr. Valon had said about the statement in the paper as to the cost of coal gas, the average which he (the author) had taken was from the "Gas World Year Book." He took a page at random, and he found the average from that book

was 4s. 6d. a thousand. But he did not want to quarrel with Mr. Valon, for he was entirely at one with him. When one was considering petrol gas one ought to compare it with what was obtained in districts right away in the country, and, surely, in outlying districts coal gas was not only very expensive, but also, he thought, scarcely as efficient as that obtained in large towns. He dared say that small gas companies had their difficulties. It was always more difficult to run a small undertaking than it was to run a big one as regards efficiency. His experience led him to believe that the purification systems of small gasworks were often a source of trouble to them.

Mr. Rawlings had mentioned humidity, and he seemed to suggest that the amount of water vapour in the air at any one time affected the amount of vapour that could be carried by that air ; but, if one believed Dalton's law, the two, being antagonistic fluids, certainly did not dissolve each other, and they did not directly influence one another as to the amount a given space would hold. They did influence one another indirectly to a small extent in that if one took a given volume of air by itself—say, one cubic foot—the amount of air in that was a cubic foot ; but if one took a cubic foot of air saturated with water vapour at a certain temperature there was not a true cubic foot of air there, although *the space* would hold the same amount of petrol as it would before. The amount of petrol vapour which could be evaporated into a cubic foot was the same whether it previously held dry air or moist air. At the temperatures ordinarily met with in this country—he did not say in India or places like that, where, of course, there was possibly a certain amount of difficulty, which, however, was easily got over by treating the air—the amount of water vapour which the air held at a normal temperature was so small that the amount of volumetric displacement was, for all practical purposes, negligible.

Mr. Currey criticised the figure in the paper of 11 cubic feet per hour for a weak-mixture gas. The test was done in a splendidly equipped laboratory, and so he (the author) knew that it was quite right. He was testing a weak gas machine, not his own. The great difficulty about testing it was that they could not get the apparatus to deliver the same gas five minutes running, so that sometimes it would have been 11 cubic feet and sometimes 9 or 6. Certainly, part of the time it was 11 cubic feet when the candle-power test was made. . As Mr. Currey had said, the pressure on the gauge was very erratic, but that was due to the fact that when it was attempted to run all the lights at once—it was a 100-light plant and there were 75 lights on it—the piping was not large enough to carry the requisite volume without a large drop in pressure. It was simply a question of pipe sizes. He granted that that was a very difficult question for a weak gas. One's pipe sizes should be very big indeed, so big that people

would not use them. They preferred to take the risk that all the lights would not be on at once. That did not apply with a rich gas so much, because it only took 4 cubic feet an hour for a burner, which was quite a reasonable figure for a coal gas burner.

Mr. Hoddle had spoken of the cost of mantles. On the London and South-Western Railway they were using these same inverted mantles for train lighting, and in France they were using upright mantles for the same purpose, so that it could not be such a serious matter. He had had mantles in his own house with coal gas for 12 months without renewing. Of course, it depended to a certain extent upon who was dealing with the thing. Sometimes a maid would come along with a big feathery brush, and away went the mantle. There were other people who were careful, and then everything was all right.

Mr. Butterfield had mentioned that he (the author) had taken acetylene without mantles and pitted it against petrol gas with mantles. He did that with his eyes open, because he had visited certain acetylene showrooms and he had seen no attempt to push mantles, nor did he see any attempt to push acetylene for cooking purposes. That might be by accident, or it might be by design. In one showroom that he went into they were not at all keen about telling him of the mantle burner. He took it that there was something peculiar about it, but did not know what it was.

It had been said that acetylene had very wide limits of explosibility, and petrol gas had very low limits of explosibility. He would look the matter up and deal with it in a written addition to his reply. The limits of combustibility for petrol gas covered a very small range—something between 1% and 4%.

Mr. Tookey had referred to the failure of incandescent mantles, particularly when used with petrol gas. He (the author) thought that it was mainly because the petrol gas people were very keen on giving an exceptionally large light unit. He did not know why it was so, but it was the fact. They fairly "busted" the gas through as a rule, and the mantles did not last long. He did not regard that as an ideal system at all. In the system which he ran and which was his business they made a point of not working at too high a pressure, and they tried to avoid roaring, with the consequence that the mantles certainly lasted almost indefinitely.

With regard to Mr. Holroyd Smith's remark that he would have liked to hear something about different plants, it was very difficult for a man in his (the author's) position, who had a plant of his own, to say anything on the subject, and he had thought it better to leave it alone in the paper, but to wait for the point to come out in the discussion. He thought that probably speakers would say something about their own plants, and then possibly he could criticise them, but as nobody had done so, it left him nothing to criticise.

Mr. Scott-Snell also communicated the following reply in writing :—

I promised in my reply to the discussion that I would give some figures as to the explosive limits of acetylene and communicate them in a written reply.

The wideness of the range over which mixtures of certain gases with air are inflammable may be taken as a sound basis in estimating the comparative safety of these illuminants. Obviously, the narrower these limits the less the possibilities of trouble from accidental ignition, and in view of this fact the following figures are interesting. In Professor Robinson's "Gas and Petroleum Engines" (p. 898) is given a table compiled from the researches of Dr. Bunte, wherein are stated the explosive limits of various gases when mixed with air. The limits of inflammability, of course, extend a little beyond these figures in either direction. Amongst others he gives the following :—

Combustible Gas.	Percentage of Combustible in air and gas mixture.		Range.
	Weakest.	Richest.	
Acetylene	3·4	52·3	48·9%
Coal Gas	7·9	19·1	11·2%
Pentane	2·4	4·9	2·5%

The limits of combustibility for acetylene were determined by Professor Clowes as lying between 3% and 82%. It will be noticed how very wide is the danger zone in the case of acetylene, and how very narrow in the case of petrol gas as exemplified by pentane. It must be remembered also that there is a great difference in the character of the explosion in the two cases, attempts to make internal-combustion engines work on the former having proved failures on account of the violent nature of the explosion.

With regard to the relative safety when used for lighting purposes, we are mainly concerned with the danger from a light coming into a room in which there has been an escape. If we consider the same size leak in each case the time taken to pour out acetylene to the extent of 3·4% of the contents of a room will obviously be very much less than the time taken for petrol vapour to escape to the extent of 2% of the same space, for in the latter case only 6% (if the mixture advocated in the paper is used) of the volume issuing from the leak is vapour. The comparative potentiality of any leakage is thus enormously reduced in favour of petrol gas.

CORRESPONDENCE ON "PETROL AIR GAS."

Mr. Geo. W. Shearer, Wh.Sc., B.Sc., A.M.I.C.E., communicates the following remarks on Mr. Scott-Snell's paper :—

"The author gives much that is of value to those interested in the manufacture of petrol air gas, particularly the curves of saturation, temperatures and pressures, and the calculation of the percentage strength of a mixture from a known quantity of petrol absorbed by a known quantity of air ; but the value of the last item would have been much increased by a definite statement as to the number of cubic feet of vapour produced by a gallon of petrol. The latter part of the paper dealing with the more practical points is less convincing, and the author's obvious leaning to the strong mixture prevents him from doing justice to the weak mixture used by many firms.

"Strong mixtures may be termed those containing above 3% of vapour, and weak mixtures those with less than $2\frac{1}{2}\%$; mixtures with percentages between $2\frac{1}{2}$ and 3% are not used, and, according to Professor Vivian Lewes, they are violently explosive. The automatic control of the weak mixture does not present the great difficulties suggested by the author, and with a well designed machine the results obtained are quite as good as can be obtained with any strong-mixture plant, and the writer knows of one weak-mixture plant which produces results which cannot be excelled by any other plant.

"It is possible to obtain from the weak mixture much higher candle powers per cubic foot per hour than that quoted by the author on page 84. The writer has obtained 50 candle power from 7 cubic feet per hour, which is much higher than the 5 quoted by the author, and condensation is not likely to give any trouble in the pipes, as even with equal wet and dry bulb thermometers of about 46° F. and ice packed so that the air supply was drawn directly through it, even with no drying apparatus in the plant, condensation was found to be almost negligible.

"Points which are not satisfactorily dealt with in the average plant are pressure governing, proportioning of air and petrol with varying number of lights, equalisation of temperature in the carburettor, and, finally, measurement of the gas used. In the plant referred to above the regulation of the richness of the mixture is effected by causing the rate of the petrol feed to be exactly governed by the rotation of the working parts of the air meter, and the varying levels of petrol in the reservoir have no effect on the rate of the petrol feed at all. There is no gasholder, and the plant is designed with minute care so that any change in the number of lights burning is instantaneously responded to, and every surface to which petrol might cling in the

feed gear is sharpened to a point, so that such surplus immediately drips back to the reservoir.

"The result has been so successful that a 50-light plant has been run for 48 hours with 1 light only requiring 1 drop of petrol per minute, and then suddenly lit up to the full capacity of the 50 lights without any visible variation in the richness of the mixture. The carburettor consists of two concentric surfaces, partly spherical and partly conical, the space between them being about $\frac{1}{8}$in., and the air is caused to sweep spirally with the petrol from the highest point between the surfaces ; the whole is immersed in water, and this water constantly circulates owing to the cold produced at the point of most rapid evaporation. This water circulation greatly reduces the temperature differences in the carburettor.

"It has been found that drying the air is not essential, and that even without drying very little water collects in the carburettor, and it can easily be drained off by a cock provided there. This plant has been installed in a number of houses which have been piped for ordinary coal gas, and has invariably given satisfaction."

Mr. E. Scott-Snell replies to Mr. Shearer's communication as follows :—

"Apropos of Mr. Shearer's suggestion that I might with advantage have given the cubic feet of vapour obtained from one gallon of petrol the following theoretical considerations may in some measure repair the omission.

"The molecular weight in pounds of any substance in the gaseous form at 0° C. and 760 m/m. occupies approximately 359 cubic feet. From this we can calculate that for hexane (C_6H_{14} sp. gr. 0·663)—

$$1 \text{ gallon occupies } \frac{359 \times 6{\cdot}63}{86} = 27{\cdot}7 \text{ cubic feet.}$$

Similar calculations for the other members of the paraffin series give :—

Pentane	..sp. gr.	0·626	gives	31·2	cubic feet per gallon.
Hexane	.. ,,	0·663	,,	27·7	,, ,,
Heptane	.. ,,	0·668	,,	24·7	,, ,,
Octane	.. ,,	0·719	,,	22·6	,, ,,
Nonane	.. ,,	0·741	,,	20·8	,, ,,

"In going through my paper again I do not find I have suggested (as Mr. Shearer alleges) any difficulty of automatic control with a weak mixture. What I really suggested was that, given a plant so badly designed that automatic control is largely a matter of luck, and hand control has to be added, then regulation of the mixture is an easier matter with a weak gas than with a strong one. My reasons for this conclusion

are given in the paper. I have not the slightest doubt that just as good results are given with the former as with the latter. The main reason for my ' obvious leaning to the strong mixture ' lies in the fear of the explosive properties of the weak one. When one has seen a gasholder that has hit the roof beams and become transformed into a very good semblance of a squashed opera hat, because a lazy attendant stopped the machine without first turning off the lights, one is encouraged to design a plant on different lines oneself ! "

Amalgamated Balance Sheet of the Society of Engineers and the Civil and Mechanical Engineers' Society, 31st December, 1909.

Liabilities.		£	s.	d.	£	s.	d.
To Sundry Creditors ..	.. S.E.	140	16	4			
,, Do. do. ..	..C.M.E,S.	10	8	0			
					151	4	4
,, Subscriptions received in advance	.. S.E.	32	9	0			
,, Do. do.	..C.M.E.S.	12	2	6			
					44	11	6
,, Life Membership Fund	.. S.E.	48	2	7			
,, Do. do.	..C.M.E.S.	21	0	0			
					69	2	7
,, Benevolent Fund ..	.. Do.				41	19	11
,, Premium Fund ..	.. S.E.				23	1	7
,, Benevolent Fund ..	.. Do.				15	0	0
,, Bessemer Trust Fund	.. Do.				154	9	6
,, Nursey Memorial Fund	.. Do.	46	7	3			
Less	..	0	2	10			
					46	4	5
,, J. Bernays' Legacy ..	.. Do.				25	0	0
,, Status Fund ..	.. Do.				12	12	0
,, Accumulated Fund	.. Do.	812	14	3			
,, Do. do. ..	..C.M.E.S.	47	14	6			
					860	8	9

Assets.		£	s.	d.	£	s.	d.
By Subscriptions in Arrear ..	S.E.	194	12	6			
,, Do. do.	..C.M.E.S.	32	18	6			
					227	11	0
,, Admission Fees in Arrear ..	S.E.	18	18	0			
,, Do. do.	..C.M.E.S.	1	1	0			
					19	19	0
					247	10	0
Less Reserve against Bad Debts	S.E.				100	0	0
					147	10	0
,, Sundry Debtors	S.E.				11	16	5
,, Amalgamation Expenses, Board of Trade Fee and Solicitor's Disbursements .					10	13	9
,, Investments (S.E.)—							
£606 L. & N.W. Rly. Co. 3% Debenture Stock ..		524	19	0			
£33 Hammersmith & City Rly. Cons. Ord. Stock..		46	7	3			
£13 N. & S.W. Junction Rly. Stock		22	16	3			

	£185 N.E. Rly. Irred. 3% Debenture Stock ..		154 9 6	748 12 0
,, Office Furniture .. .. S.E.			47 6 6	
,, Do. .. ..C.M.E.S.			1 10 0	48 16 6
,, Library .. .. .. S.E.			40 0 0	
,, Do. .. .. ..C.M.E.S.			5 5 0	45 5 0
,, Stock of Transactions .. S.E.			38 13 0	
,, Do. do. ..C.M.E.S.			2 19 0	41 12 0
,, Cash at Bank ..				
Current a/c .. S.E.	61 14 0			
Do. do...C.M.E.S.	41 12 9	103 6 9		
Deposit a/c .. S.E.	220 0 0			
Do. ..C.M.E.S.	50 0 0	270 0 0		
Special a/c .. S.E.		15 0 0		388 6 9
,, Cash in hands of Secretary .. S.E.			3 3 6	
Less Petty Cash Overdraft C.M.E.S.			2 1 4	1 2 2
£1,443 14 7				£1,443 14 7

THE SOCIETY OF ENGINEERS (INCORPORATED).

Balance Sheet, 31st December, 1910.

Liabilities.	£	s.	d.	£	s.	d.
To Sundry Creditors				177	11	2
,, Subscriptions received in advance ..				29	18	3
,, Life Membership Fund				69	2	7
,, Premium Fund (Society's)				22	12	4
,, Special Premium Fund				10	10	0
,, Status Fund				12	12	0
,, Benevolent Fund				56	19	11
,, General Reserve Account ..						
Balance Jan. 1, 1910	100	0	0			
Deduct Expenses of Amalgamation of The Society of Engineers and Civil and Mechanical Engineers' Society	73	11	10			
,, Balance carried to Accumulated Fund	26	8	2			
,, Accumulated Fund—						
Balance at credit thereof as per Amalgamation Account, Jan. 1, 1910	860	8	9			
Less Interest accrued written back	7	16	10			
	852	11	11			
Add General Reserve Account Balance	26	8	2			
Add Excess of Income over Expenditure for the year	65	2	6			
				944	2	7

Assets.	£	s.	d.	£	s.	d.
By Subscriptions in arrear, estimated value—						
Previous to 1910	97	3	0			
Year 1910	129	3	0			
				226	6	0
,, Admission Fees in arrear—						
Previous to 1910	9	9	0			
On account of 1910	10	10	0			
				19	19	0
,, Sundry Debtors				15	19	4
,, Investment £606 London & North-Western Rly. Co. 3% Debenture Stock as per Amalgamation Account Jan. 1st, 1910				524	19	0
,, Office Furniture as per Amalgamation Account	48	16	6			
Less Depreciation written off ..	4	17	8			
				43	18	10
,, Library as per Amalgamation Account				45	5	0
,, Stock of Transactions and Journals ..				47	2	6
,, Lectures on the Law relating to Engineering, net cost at date				12	11	6
By Cash at Bank						
On Current Account	115	0	0			
On Deposit Account	250	0	0			
On Special Account..	15	0	0			
	380	0	0			

To BESSEMER TRUST FUND	154 9 6			,, Cash in hands of Secretary	10 18 6			
Excess of Income over Expenditure ..	5 4 6					390 18 6		
		159 14 0		,, BESSEMER TRUST FUND INVESTMENT—£185 N.E.Rly. Irredeemable 3% Debenture Stock, value as per Amalgamation Account, 1st Jan., 1910	154 9 6			
,, NURSEY MEMORIAL FUND..	46 7 3			,, NURSEY MEMORIAL FUND INVESTMENT—£33 Hammersmith & City Rly. consolidated Ordinary Stock, as per Amalgamation Account, 1st Jan., 1910..	46 7 3			
Less overpaid for Premiums	4 14 10							
		41 12 5						
,, J. BERNAYS' LEGACY ..	25 0 0			,, BERNAYS' LEGACY INVESTMENT—£13 N. & S.W. Junction Rly. Stock, as per Amalgamation Account, 1st Jan., 1910	22 16 3			
Excess of Income over Expenditure ..	0 17 5					223 13 0		
		25 17 5						
			227 3 10					
			£1,550 12 8			£1,550 12 8		

SOCIETY'S PREMIUM FUND.

	£ s. d.		£ s. d.	£ s. d.
To Premiums	7 9 6	By Balance as per Amalgamation A/c	23 1 7	
,, Gold Medals	11 7 6	*Less* Interest accrued written back	2 12 3	
,, Balance carried to next Account	22 12 4			20 9 4
		Presidents' Donations		21 0 0
	£41 9 4			£41 9 4

(*Continued next page.*)

BALANCE SHEET, 31ST DEC., 1910. *(Continued from preceding page.)*

NURSEY MEMORIAL FUND.

	£ s. d.		£ s. d.
To Balance at 1st January, 1910	0 2 10	By Dividends	1 14 3
,, Premiums	6 6 3	,, Balance carried to next Account	4 14 10
	£6 9 1		£6 9 1

BESSEMER TRUST FUND.

	£ s. d.		£ s. d.
To Balance carried to next Account	5 4 6	By Dividends	5 4 6

J. BERNAYS' LEGACY.

	£ s. d.		£ s. d.
To Balance carried to next Account	0 17 5	By Dividends	0 17 5

We have examined the above Balance Sheet and accompanying Accounts, and have obtained all the information and explanations we have required. In our opinion the Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Society's affairs, according to the best of our information and the explanations given to us, and as shown by the books of the Society.

23, Queen Victoria Street, E.C.,
15*th March*, 1911.

(Signed) W. B. KEEN & CO.,
Chartered Accountants.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st DECEMBER, 1910.

	£	s.	d.	£	s.	d.
To Printing Transactions..	188	9	6			
Less Sales and Advertisements ..	22	5	1			
				166	4	5
,, ADMINISTRATION EXPENSES—						
Salary of Secretary	243	6	8			
Rent of Offices and Hire of Rooms..	91	6	0			
Fuel, Lighting, Office Cleaning, and Repairs	23	10	1			
Postage, Telegrams, Carriage, and General Expenses	103	10	9			
Stationery and General Printing ..	99	8	7			
				561	2	1
,, MEETING EXPENSES—						
Reporting Meetings..	16	16	0			
Refreshments for Members at Ordinary Meetings	7	6	4			
				24	2	4
,, Dinner : Balance				51	8	8
,, Law Charges				6	9	6
,, Depreciation on Office Furniture ..				4	17	8
,, BALANCE carried to Accumulated Fund Account— *Excess* of Income over Expenditure for the year				65	2	6
				£879	7	2

	£	s.	d.	£	s.	d.
By Subscriptions for the year	885	10	6			
Less Amounts written off	58	13	9			
				826	16	9
,, Admission Fees				26	15	6
,, Interest on Deposit				7	3	8
,, Interest on Investment (London & North-Western Railway Co. 3% Debenture Stock)				17	2	4
,, Vacation Visits : Balance				1	8	11
				£879	7	2

April 3rd, 1911.

THE ADMINISTRATIVE ASPECT OF WATER CONSERVANCY.

By William Ralph Baldwin-Wiseman, M.Sc., Assoc.M.Inst.C.E., P.A.S.I.

General Introduction.

Various Royal Commissions, such as those on Salmon Fisheries, in 1902, and on Sewage Disposal, in 1903, and select Committees of both Houses of Parliament, on Canals, in 1883, and on the Water Supplies Protection Bill, in 1910, have recommended in their several Reports the development of some general system of water conservancy, yet despite the weightiness of these recommendations, the frequent advocacy of the subject during the past four decades by various individuals in speeches, papers and books, and the further fact that continued neglect of the subject must eventually affect the pockets, if not the health of the community, the subject has received much less public attention than has been given to matters greatly inferior in economic importance. Even amongst those who are well acquainted with the awful condition of the rivers flowing through the densely populated industrial districts, with the keenness of the competition for the rapidly diminishing number of unappropriated reservoir sites, and with the increasing friction between millowners, riparian proprietors and local authorities, and between the various authorities and individuals drawing upon the sub-surface waters, there are many who prefer to leave the problem with its ever increasing complexity to be solved by posterity, at a greatly increased cost, rather than submit to any immediate increase in taxation. In this respect the subject has not been advanced by those individuals who have advocated the development of conservancy authorities charged with sectional interests, each of which would give rise to an increased taxation, without, effecting that economical development of the natural resources which would eventuate with an administration created under a broad and comprehensive scheme of conservancy.

A System of Water Administration.

At the present time conservancy, such as it is, is vested in divers authorities, some of which individually are very efficient, but collectively are inefficient, owing to lack of co-ordination, and although, as shewn in Table I., the supreme control of certain

branches of conservancy has been transferred from one authority to another, there does not appear to have been any very consistent tendency towards concentration of authority, with regard to water administration, in any one of these bodies. As most of these authorities are already charged with a multiplicity of duties it would appear to be most expedient to create a new department—the Hydrographic Board under a Minister of Water Supply—to administer this most important subject, transferring to it all the varied powers now vested in the several Government departments and expanding and amending these powers as experience may subsequently dictate.

Acting under this department there should be District Boards, charged with the administration of main drainage areas, or groups of river basins, and Rivers Boards each in charge of some river basin, which should be classed as major or minor rivers boards, according to the size and economic importance of the basin under their charge.

A few of the larger basins might be more conveniently administered by two boards, in charge respectively of the upper and lower sections of the basin, while some of the smaller basins might with advantage be administered by the board of a contiguous river basin.

Both the district and river-boards should be as fully representative as possible, not only of the local authorities, but of all the conservancy interests, such as water supply, inland navigation, drainage, fishery and sub-surface waters, within the area of their jurisdiction, and while the river board would act as the sole conservators of their particular basin, the district board would co-ordinate the work of their constituent rivers boards, enforce a uniform system of procedure and adjust any disputes which might arise between rivers boards, local authorities, trading companies and individuals, subject however to revision on appeal by the Hydrographic Board.

This board should publish an annual report, divided into sections, each dealing with some branch of conservancy work, such for instance as stream flow, underground water levels in the more important formations, floods, water supply, sewage disposal, inland navigation, fishery, finance, digest of cases, reports on investigations and enquiries and on the progress of administration in other countries.

It should enforce a uniform system of procedure throughout the country, subject however to modification, to meet the almost endless variety of local needs and circumstances, and should promote legislation to enforce the settlement of cases where water is in dispute, to formulate a differential system of rating and to mould the complexities of the existing law with regard to water supply, inland navigation, etc., into a comprehensive and uniform water code.

Such an organisation should not, however, be created until an exact survey of the national water resources has been made, and a system of hydrographic records has been established and Parliament has in its possession data such as that arising from the investigations undertaken by the governments of the U.S.A., France, Italy, Austria, India, Victoria, and the Transvaal with regard to stream flow, or of Bavaria, Norway, and Sweden with regard to water power.

To effect this a hydrographic survey staff, consisting of salaried, subsidised, and voluntary assistants, should be at once organised, to work in conjunction with a statistical bureau, charged with the compilation and publication of data collected by the survey and amplified with all available data extracted from existing records and from returns which, under the powers of a short Act, should be compulsorily rendered by all local authorities and companies in charge of works of water supply, by all sewage disposal, drainage, inland navigation and fishery authorities and by all owners of pumping plant in excess of a certain capacity.

The organisation of this survey, so essential both to the formation and to the continuation of an exact and economical system of conservancy, need not entail any exorbitant expenditure, since in fact a fraction of a penny in the pound on the rateable value of England and Wales should be amply sufficient to maintain the survey, judging by the examples afforded by other countries.

Thus the appropriation for the Irrigation branch of the Geological Survey of the U.S.A.[1] was £7,475 in 1891, expended as follows :—

£4,164	for services.
197	for travelling expenses.
594	for field subsistence.
2,520	for books, stationery, etc.

Eleven years later the expenditure was :—

£7,175	for salaries.
1,025	for instruments.
12,300	for surveying and gauging.

And during 14 years the annual appropriations for stream gauging have varied as shewn below :—

2 years,	1894 and 1895	£2,562	
1 year,	1896	6,150	
4 years,	1897 to 1900	10,250	
2 ,,	1901 and 1902	20,500	
4 ,,	1903 to 1906	41,000	(700 gauging stations)
1 year	1907	30,750	

1. Annual Report of the Director of the Geological Survey of the U.S.A., Washington, D.C., 1891, etc.

the appropriation being reduced in the last recorded, year as a considerable sum was then being expended on the Reclamation Service, to which many officers of the former service were transferred.

In Victoria,[2] where 232,012 acres were at the time under irrigation £3,197 was expended on stream gauging and surveys during the year ending 30th June, 1908, and £2,600 was put down as the estimated expenditure during the year ending 30th June, 1909.

In the Transvaal,[3] where 11 hydrographic districts aggregating 14,000 square miles are under observation and the survey regularly reports on the flow of 15 rivers, the expenditure for the last three years on record was :—

	1905-6.	1906-7.	1907-8.
	£	£	£
Salaries, wages and allowances	18,633	19,167	15,335
Transport and travelling ..	4,814	2,926	3,025
Hydrographic surveying ..	10,075	6,946	5,487

For the year ending 30th June, 1906, the survey had the assistance of an auxiliary staff of 23 honorary and 50 subsidised observers for a total expenditure of £1,000.

In the Dominion of Canada[4] the appropriation for the three newly constituted irrigation districts, each in charge of an hydrographer and his assistant, was £2,083 in 1908 and 1909 respectively.

Such a body should be created forthwith, but before any field or observational work is undertaken, a comprehensive, uniform, and continuous scheme for collecting and presenting the data should be drafted, or otherwise its work will suffer from the basic defect of much of the existing data—lack of compaıative value. Thus, by way of illustration, there is in existence an enormous amount of data on underground water, scattered in all sorts of publications, it is true, but nevertheless available after a more or less arduous search, much of which for all practical purposes is intrinsically worthless, owing to the omission of some essential data.

2. Third Annual Report of the State Rivers and Water Supply Commission, Melbourne, 1908.
3. Annual Report, Transvaal Irrigation and Water Supply for year ending 30th June, 1906, Pretoria, 1907.
Administrative Report, Land and Irrigation Department of the Transvaal for years July 1st, 1906 to June 30th, 1908, Pretoria, 1909.
4. Annual Report of the Hon. the Secretary of the Interior, Ottawa 1908.

With a survey collecting data on a sound statistical basis, an invaluable record would in the course of a few years be available for adjusting differences, and for outlining future development at such time, as Parliament in its wisdom, hearkens to the recommendations of various Royal Commissions, Select Committees and individuals during the past four decades and inaugurates a national system of conservancy.

The Variation in the Characteristics of Basins.

If an efficient conservancy scheme is to be formulated, steps will have to be taken to overcome the difficulties arising from the extreme diversity in the characteristics of the river basins, a few of the more important of which are detailed herewith. According to the Report of the Select Committee of the House of Lords on Conservancy Boards in 1877, there were 210 rivers in England and Wales draining 54,971 square miles ; a more recent Report,[5] issued in 1908, gives 215 river basins with a total area of 57,919 square miles, but this should be increased to 217 river basins, with a total drainage area of 57,936 square miles, by the addition of two small drainage areas in Lancashire and Cornwall respectively, which are omitted from the second summary.

This figure is used throughout the paper, and in Tables II., IV., VI., VII. and VIII., although it differs from the area of the whole country according to counties by 385 square miles, or about 0.6 per cent. of the total area of 58,321 square miles, the defect occurring mainly in those counties with an extensive coast line or a considerable proportion of estuarial area, as shewn in Table IX.

I. *Area.*—Of the 217 river basins for which a detailed analysis according to area is given in Table II., 108 river basins aggregating 52,671 square miles, occupy 90.9 per cent. of the total area of the country, the remaining 109 river basins have an aggregate area of only 5265 square miles, and of these 26 have an aggregate area of but 464 square miles, as shewn below :—

Number of basins.	Range of area in square miles.	Aggregate area in square miles.	Average area in square miles.
13	21 to 29	327	25·2
9	10 to 19	114	12·7
4	3 to 8	23	5·7
26	3 to 29	464	17·9

Obviously some of these would be of too little importance to be administered by a separate river board.

5. Report of the Royal Commission on Canals and Waterways, Vol. IV., London, 1908.

II. *Geological Structure.*—The classification of the strata of the whole country according to its permeability or otherwise, is as follows :—

Impermeable strata	10,800 sq. miles	= 18·6%	of the total area.
Partially permeable strata ..	10,800 ,,	= 18·6%	,, ,,
Permeable strata	21,700 ,,	= 37·2%	,, ,,
Impermeable capping permeable strata	15,000 ,,	= 25·6%	,, ,,
	58,300 ,,	=100·0%	,, ,,

And the geological structure of a basin is so varied, that in all probability each of the principal water-bearing formations would have to be studied as an entity, rather than sectionally, within the confines of individual drainage areas, since, as the author has shown in another paper,[6] the direction of sub-surface flow is more directly dependent on the geological structure and the line of outcrop of the strata, than on the surface configuration of the area, although of course the geological structure somewhat influences this latter characteristic.

III. *The ratio of Urban to Rural Area.*—Of the whole 217 basins, 48 are entirely rural, and in the remaining 169 river basins 12 per cent. of their aggregate area is urban and 88 per cent. rural. The details of 73 basins with urban areas ranging from 88.3 per cent. to 10.0 per cent. of the total area, are shewn in Table III. and the percentage ratios of urban to rural area for the whole country are summarised below :—

Number of River basins.	Total area in		Percentage of aggregate area of group.	
	Thousands of sq. miles.	In terms of whole country as unity.	Urban.	Rural.
73	22·1	0·382	20·5	79·5
104	30·3	0·523	5·8	94·2
169	52·0	0·898	12·0	88·0
48	5·9	0·102	—	100·0
217	57·9	1·000	10·8	89·2

IV. *Density of Population.*—As it was extremely difficult to apportion, with any degree of exactitude, the population of rural areas in any particular river basin, and as the population of the rural areas of the whole country only aggregates 21.2 per cent. of

6. W. R. Baldwin-Wiseman, The influence of pressure and porosity on the motion of sub-surface water, Quart. Journ. Geol. Soc., Vol. LXIII., London, 1907.

the total population, the author concerned himself solely with an investigation of the density of the urban population in the several river basins, the result of which is detailed in Table IV. This urban population of 28.1 millions, or 78.8 per cent., of the total population of the country, is located in 1162 urban areas, distributed in 169 river basins as shewn below :—

Class of District.	Number of River Basins.	Urban area in sq. miles.	Urban population. In millions.	Urban population. As a percentage of the total.
London and 28 Metropolitan Boroughs	2	117	4·8	13·5
74 County Boroughs..	39	843	11·8	33·1
249 Boroughs	101	1,201	4·5	12·6
810 Urban districts ..	145	4,083	7·0	19·6
1,162 Urban areas ..	169	6,244	28·1	78·8

Further, more than one half of the urban population of the whole country is concentrated in four river basins, aggregating less than one-fifth of the total area of the country, and no less than three-fourths of the urban population are located in thirteen river basins, with an aggregate area of about one-third that of the whole country, from which and the preceding section it is evident, as one is well aware, that problems of stream pollution and of water supply will be much more acute in certain basins than in others.

V. *Rateable Value.*—In all questions of improvement one has to consider the rateable value of the area, and here it is most apparent that some system of national administration must be adopted, for whilst the rateable value of some few river basins such as that of the Thames, Mersey, Trent and Ouse is enormous, that of other river basins is extremely small.

For a similar reason to that already given when dealing with the density of the population, the author made no attempt to apportion the rateable value of the rural areas, which only amounts to about 25.6 per cent. of the rateable value of the whole country, but dealt solely with that of the urban areas, the figures were abstracted from the most recent return,[7] which he had at hand at the time of preparing the statistics summarised in

7. Return to an Order of the House of Commons, Loans contracted by Local Authorities, London, 1908.

Table VII., but differ by £2.6 millions, or about 1.2 per cent. of the total, from the most recent taxation return.[8]

Areas.	Rateable value in millions of £'s.	
London and 28 Metropolitan Boroughs	44 ·6	
74 County Boroughs	54 ·1	
249 Boroughs	22 ·4	
810 Urban districts	37 ·6	Corrected
1,162 Urban areas	158 ·7	156 ·1
62 Counties, 656 Rural districts	53 ·8	53 ·8
Whole country	212 ·5	209 ·9

The rateable value of the urban area of four river basins aggregates 59.3 per cent. of the total urban rateable value of the country and that of 19 river basins aggregates over four-fifths of the total as shewn below :—

Number of River Basins.	Rateable Value of the Urban Area in Millions of £'s. Maximum. For a single River Basin in the group.	Minimum. For a single River Basin in the group.	Total.	Terms of that of the urban area of the whole country as unity.
1	—	—	57 ·7	0 ·370
3	14 ·2	7 ·7	34 ·7	0 ·223
4	3 ·8	3 ·5	14 ·4	0 ·092
3	2 ·7	2 ·5	7 ·8	0 ·050
8	1 ·9	1 ·1	10 ·5	0 ·067
19	57 ·7	1 ·1	125 ·1	0 ·802

VI. *The number of Local Administrative Authorities.* The extreme diversity in the number of local administrative authorities is well shewn in Table V. and in the following summary.

8. Local Taxation Returns, 1906-7, Part 1, London, 1908.

Class of Local Authority.	Number of Authorities.	Number of River Basins in which they are distributed.	Maximum number of this class of authority in a single river basin.
County Council ..	62	217	17
County Borough Council ..	74	39	10
Borough Council ..	278	103	53
Urban District Council ..	810	145	87
County Borough, Borough and U.D. Councils	1,162	169	143

This diversity is still further accentuated, from an administrative point of view, by the fact that while some authorities own and control a water supply, treat their own sewage and have representatives upon drainage and fishery boards, others delegate the work of water supply and sewage disposal to Joint Boards, of which, excepting two or three joint committees of rural district councils, there are: 22 Joint Water Boards in 19 river basins and 10 main drainage areas; and 34 Joint Sewerage Boards in 19 river basins and 8 main drainage areas; others again although nominally classed as local authorities affording water supplies, are merely distributing agents in their own area, purchasing the water in bulk from one or more water companies, local authorities, private individuals or industrial companies.

A few of the large local authorities own reservoirs in a distant drainage area and have interests not only in their own administrative area and in the remote river basin where their reservoirs are located, but also in the intermediate river basins, through which their aqueduct passes, for not infrequently they supply a considerable number of local authorities *en route*; thus for instance, 3 civic authorities have direct or indirect interests in no less than 20 river basins as shewn below:—

City.	Reservoirs.	Length of aqueduct in miles.	Number of basins.
Liverpool ..	Vyrnwy	68·5	5
,, ..	Rivington	21·0	3
Manchester ..	Thirlmere	95·9	8
,, ..	Longdendale	17·8	1
Birmingham ..	Elan Valley	73·7	3

and would doubtless claim representation on most of these boards when created.

VII. *Industrial and Economic Importance.* The commercial interests are not only extremely varied, but also extremely difficult to differentiate and estimate. The author has already in the preceding section indicated the extreme complexity with regard to the administration of water supply, and the difficulty is still greater if one attempts to apportion expenditure and capital cost in a general way to the several river basins, so also with regard to inland navigation, drainage, fisheries and other interests; the author therefore proposes in this section to deal solely with the totals for the whole country, but suggests in passing that exact data should be obtained by the proposed hydrographic survey or other investigating authority in the future.

The total capital investment in hydraulic works in this country is not far short of £250,000,000, of which public and private water supply works account for about 54.0 per cent. of the total, made up as follows :—

		Millions £
Private installations affording industrial and domestic supplies		1·5
221 Public Water Companies	.. ..	18·7
848 Local Authorities	County Borough & Borough Councils	57·6
	Urban District Councils	5·4
	Rural District Councils..	1·5
22 Joint Boards		50·3
	Total	135·0

A further sum representing 17.3 per cent. of the total has been expended upon navigable waterways as shewn below :

				Millions £
Independent Canals ..	2,456·5	miles.	Paid-up capital ..	34·2
Railway owned Canals	965·2	,,	,, ,, ..	4·2
,, controlled Canals	218·5	,,	,, ,, ..	4·9
Total ..	3640·2	,,	,, ,, ..	43·3

These waterways are located in but 62 river basins, in some of which basins there are several waterways, whilst 155 river basins have no navigable waterways of any importance in them ; in a few cases (such as for instance, the Leeds and Liverpool and the Grand Junction Canals, each traversing 6 basins, and the Lancaster Canal traversing four basins), some canals traverse several basins, all of which is liable to give rise to complications in the administration of the basin or in the constitution of the administrative authoiity.

The remaining 23.7 per cent. of the above-mentioned estimate is represented by the capital expenditure upon works of sewage

disposal, drainage, flood prevention, river improvement, and fisheries, which latter branch of conservancy is under the administration of three Conservancy Boards, 53 Fishery District Boards and various local Associations, the boundaries of the administrative areas of which bodies but rarely coincide with those of the river basins.

The Grouping of River Basins.

The extreme diversity of river basins is somewhat masked by grouping them according to some scheme, such as those which have been proposed from time to time, and uniformity of administration will doubtless be effected by constituting main drainage boards.

The members of the Royal Commission on the Prevention of the Pollution of Rivers in their Sixth Report suggested the division of the river basins of Great Britain into five groups as follows :—

No. of Group.	Name of Area.	Direction of Drainage into	Limits of area of Group.
1	East Britain ..	North Sea ..	John o' Groats to South Foreland.
2	South England	English Channel	——
3	Severn.. ..	Bristol Channel	——
4	Welsh	Irish Sea ..	St. David's Head to Mull of Galloway.
5	West Scotland	North Atlantic	——

Professor D. T. Ansted[9] divided the river basins of the United Kingdom into 18 groups, of which only those numbered from 1 to 8 are of any concern here, as those numbered from 9 to 13 refer to Scotland and from 14 to 18 to Ireland. His grouping of the English and Welsh basins, which is shewn on the accompanying map, is as follows :—

No. 1. Thames basin.
,, 2. South coast basin.
,, 3. South-western basin.
,, 4. Severn and Welsh coast basin.
,, 5. East coast basin.
,, 6. Humber basin.
,, 7. North-east coast basin.
,, 8. North-west coast basin.

9. D. T. Ansted, Water and water supply, London, 1878.

Later Mr. de Rance[10] urged that no division of river basins could rest on a truly natural basis if the geological structure of the area was not considered, and he divided the country into 13 groups of basins as follows :—

No. 1. North-east basin.
,, 2. Basin of the Humber.
,, 3. Basin of the Wash.
,, 4. Basin of the Thames and East coast streams.
,, 5. South coast catchment area between the Wealden and Purbeck anticlinals.
,, 6. South coast streams draining into West Bay.
,, 7. South Cornish basin.
,, 8. North Cornish and Devon basin.
,, 9. Severn basin.
,, 10. South Wales basin.
,, 11. West Wales basin.
,, 12. North-western basin.
,, 13. North-western basin north of the Central watershed.

This system is by no means complete, since in one or two cases portions of a single river basin are included in two different groups, nor is it in complete agreement with its author's fundamental axiom, on which it is supposed to be based ; thus for instance, the Trias sandstone and the Chalk, with areas respectively of 7,500 and 8,900 square miles are disposed, the former in 35 river basins in 9 main drainage areas and the latter in 59 river basins in 6 main drainage areas.

The author has somewhat altered this arrangement and suggests the following :—

No. 1. East border drainage area.
,, 2. North-east ,, ,,
,, 3. East ,, ,,
,, 4. Metropolitan ,, ,,
,, 5. Channel ,, ,,
,, 6. Southern ,, ,,
,, 7. South-western ,, ,,
,, 8. Midland ,, ,,
,, 9. South Wales ,, ,,
,, 10. Western ,, ,,
,, 11. North-western ,, ,,
,, 12. Northern ,, ,,

and this order has been followed in preparing the statistics of Tables VII. and VIII.

10. C. E. de Rance, The water supply of England and Wales, London, 1882.

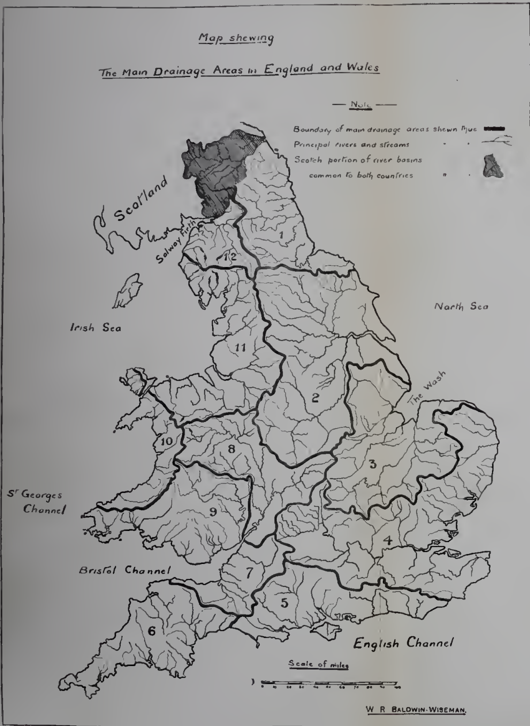
Conclusion.

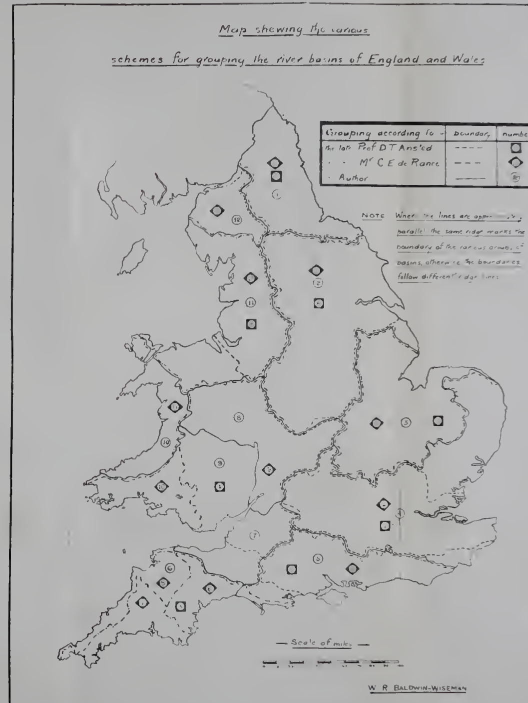
If the suggested water authorities are to be truly representative, a departure must be made from the present legislative tendency of investing county and county borough councils with supreme local conservancy powers, as under such a system 249 non-county boroughs, exclusive of the metropolitan boroughs, and 810 urban districts, with a rateable value equivalent to 28.3 per cent. of that of the whole country, will be excluded from direct representation, in addition to other interests such as water supply and navigation companies; but if the existing practice is to continue, then in order to ensure uniformity in the procedure and work of the river boards a standing committee of each county council will have to be appointed, to serve on the several rivers boards in which it is interested, for as shewn in Table VII. there are only 145 river basins with an aggregate area of 13,376 square miles, or less than one-fourth of the area of the whole country, which are located within the borders of single counties and the remaining three-fourths are distributed amongst various combinations of counties ranging from 2 to 17. Similar remarks apply to county borough councils, of which there are 74, the distribution ranging from 1 to 10 in a single basin.

Some years ago Mr. de Rance published a map,[11] in which he sought to shew that county and basin boundaries were approximately coincident, but a careful investigation shews this is not the case and that the boundaries are but rarely coincident. Thus for instance, Lancashire includes within its borders 7 entire basins and portions of 7 others, yet the boundaries of these basins coincide with the county boundary for a distance of only 14 miles, and in the case of the Thames the boundaries of its basin only coincide with those of the counties, through or by which it flows, for a distance of 17 miles.

Everyone is agreed that something must be done towards setting the house in order in regard to the conservancy of the national water resources, but as data are so essential not only to the organisation but also to the continuance of the new regime, it behoves all engineering and allied societies to participate in its inauguration, by doing their utmost to circulate and publish all information, on questions of conservancy, at the disposal of their members, and by frequent discussion of the subject in its varied aspects, to assist in the removal of the difficulties with which it is encumbered.

11. C. E. de Rance, Map of the river basins in county groups, n.d., London, circ. 1890.


Map shewing
The Main Drainage Areas in England and Wales
— Note —
Boundary of main drainage areas shewn thus
Principal rivers and streams
Scotch portion of river basins
common to both countries
Scotland
Solway Firth
Irish Sea
North Sea
The Wash
St Georges Channel
Bristol Channel
English Channel
Scale of miles
W R BALDWIN-WISEMAN.


Map shewing the various
schemes for grouping the river basins of England and Wales
Grouping according to - | boundary | number
the late Prof D T Ansted
Mr C E de Rance
Author
NOTE
— Scale of miles —
W R BALDWIN-WISEMAN

APPENDICES.

Table No.

TABLE No. II.

Shewing an Analysis of the River Basins in England and Wales according to Area.

Number of Basins.	Drainage Area					Total length of the streams in the several groups of basins, in miles.	Average drainage area in square miles per mile of stream, in the several groups.
	In square miles.				As percentage of the total area of the country.		
	Maximum.	Minimum.	Mean.	Total.			
9	4,613	1,077	2,484	22,359	38·6	3,990	5·6
18	915	514	722	12,992	22·4	2,000	6·4
81	477	100	214	17,320	29·9	2,960	5·8
52	94	50	70	3,620	6·2	690	5·2
57	48	3	29	1,645	2·9	330	5·0
217	4,613	3	267	57,936	100·0	9,970	5·8

TABLE No. III.

Shewing the Ratio of the Urban Area in any Basin to that of the Basin for all cases where the ratio is greater than 1·10.

Number of River Basins.	The Ratio of the Urban Area to that of the basin as unity.			Area of the basins in square miles.		
	Mean	Maximum	Minimum	Total for the group.	Largest basin.	Smallest basin.
	of the group.					
2	·853	·883	·804	150	94	56
1	·713	—	—	87	—	—
3	·616	·662	·610	1,898	885	198
4	·556	·571	·516	259	94	31
5	·464	·482	·425	489	168	40
3	·365	·398	·333	241	114	39
14	·229	·278	·203	1,907	585	12
41	·139	·198	·100	17,122	4,613	11
73	·205	·883	·100	22,153	4,613	11

TABLE No. I.

Shewing the Supreme Authority in various Branches of Conservancy, the Crown and the Houses of Parliament being in all cases omitted.

Branch of Conservancy.	Date of the First Act	The Supreme Authority or Authorities.	Date of Assumption of Authority.	Remarks.
1. Flood prevention, drainage of land, and irrigation	1225 §	Lord Chancellor	1427*	*6 Hen. VI. c. 5. §9 Hen. 3.
		Lord Chancellor, Lord Treasurer, and the Chief Justices	1531	
(Flood prevention)	1428	EnclosureCommissioners	1864*	*27-28 Vic. c. 114.
		Land Commissioners	1882*	Settled Land Act, *45-46 Vic. c. 38, same body as preceding with extended powers and duties.
		Board of Agriculture	1889*	*Board of Agriculture Act, 52 Vic. c.
		Development Commissioners	1909*	Only an interest in this branch of economic development. *9 Edw. VII. c. 47.
2. Freshwater Fisheries ..	1285*	Home Office	1861	*Statute of Westminster, 2 c. 47. 13 Edw. 1.
		Board of Trade	1886	
		Board of Agriculture and Fisheries	1903*	*Board of Agriculture and Fisheries Act, 3 Edw. VII. c.
3. Prevention of Stream Pollution	1388*	Local Government Board	1888	*12 Ric. II. c. 13.
4. River Improvement ..	1399*	Board of Trade	1888	*Statute 1 Hen. IV. c. 12.
5. Inland Navigation .. .	1423†	,, ,,	1888*	†2 Hen. VI. c. 9. *Railway and Canal Traffic Act, 51-52 Vic. c.
6. Water Supply, Local Authorities	1543*	Local Government Board	1888	*Act authorising City of London to impound springs within a 5-mile radius of City.
Water Supply, Companies ..	1605* & 1619*	Board of Trade	1862	*City of London (New River Co.'s) Act, 3 Jac. I: c. 18. *Charter of Incorporation, New River Co.
7. Sewage Disposal	1848	General Board of Health	1848*	*Public Health Act. Metropolitan Sewers Act. 11-12 Vic. c.
		Committee of Privy Council	1858	
		Home Office (L.G.B. Dept.)	1871*	*Local Government Act 34-35 Vic. c. 70.
		Local Government Board	1888*	*Local Government Act 51-52 Vic. c. 41.
8. Rainfall Observation (Meteorological Office)		Board of Trade	1854	
		Treasury	1905	
9. Underground Water (Memoirs of the Geological Survey)		Ordnance Survey	1832	
		Commissioners of Woods and Forests	1845	
		Department of Science and Art	1853	
		Board of Education	1899	Same body as preceding with extended powers and duties.

† These dates are the first authentic dates which the author can find, failing to trace the dates of the grants to Richard de Rulos to drain Deeping Fen *circa* 1120 A.D. and to Godfrey de Lucy to make the Itchen navigable beyond Winchester *circa* 1200 A.D.

TABLE No. V.

Shewing the Distribution of Local Administrative Authorities in River Basins

Class of Authority	Number of Basins in which the several classes of Authority in any single basin aggregate. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19	20	21	25	30	35	40	52	53	67	69	76	87	90	91	92	143	Details of the maximum number of each class of Authority in any single Basin: No. of the Separate Authorities	No. of the River basin.	No. of the Main drainage area	Total: Population in thousands in area.	Total: Rateable Value of area in £1000	Total: Area in square miles.
Counties ..	145	34	19	10		3		1	1	1	—	1	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17	128	4	—	—	3,955
County Boroughs	27	5	2	3	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		10	72	2	1,762	7,928	112
Boroughs ..	61	22	7	3	4	—	—	—	—	2	—	—	1	—	1	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	53	128	4	4,991	46,269	192
Urban Districts	54	31	19	11	6	2	—	3	3	2	1	1	1	—	2	1	2	—	—	—	—	1	1	—	—	—	1	1	1	1	—	—			87	128	4	1,673	9,528	435
.. Authorities	49	32	26	18	8	6	3	3	2	2	2	1	2	2	—	1	1	1	1	1	2	—	—	1	1	—	—	—	—	—	1	1	1	1	143	128	4	6,958	57,654	658

TABLE No. VI

Shewing an Analysis of River Basins according to their County Distribution.

Number of River Basins.	Number of Counties: Participating in any single River Basin	Number of Counties: In which such River Basins lie.	Total area of the River Basins: in square miles	Total area of the River Basins: As a percentage of the area of country	Area of Basins in square miles: Maximum	Minimum	Mean
145	1	27	13,376	23·06	434	3	92
34	2	30	7,733	13·35	794	39	227
19	3	31	8,833	15·25	1,130	46	465
10	4	27	7,034	12·14	1,842	319	703
3	6	14	2,652	4·58	1 079	760	884
1	8	8	1,077	1·86	–	—	—
1	9	9	1,609	2·76	–	–	—
1	10	10	4,052	6·99	—	—	—
1	12	12	2,607	4·50	—	-	—
1	15	15	4 350	7·51	—		—
1	17	17	4,613	7 96			
217	–	62	57,936	100·00	4,813	3	267

TABLE No VII

Shewing the Number of Authorities in each Main Drainage Area, together with the Population Resident in the several Areas, the Rateable Value and the Extent of the Several Areas.

Number of the Main Drainage Area	No. within each Main Drainage area of: River Basins.	Counties.	County Boroughs	Non-county and Metropolitan Boroughs	Urban Districts	All Urban Authorities.	Population in thousands in the: County Boroughs.	Non-county and Metropolitan Boroughs.	Urban Districts.	Whole Urban Area.	Rateable value in thousands of £ sterling of the: County Boroughs	Non-county and Metropolitan Boroughs.	Urban Districts.	Whole Urban Area.	Area in square miles of the: County Boroughs	Non-county and Metropolitan Boroughs	Urban Districts.	All Urban Districts.	Rural Districts.	Main Drainage Area.
1	16	5	7	9	51	67	900·7	244·2	582·4	1,727·3	4,245·0	1,033·8	1,602·6	7,081·4	44	32	244	320	3,382	3,702
2	14	14	19	34	210	263	3,704·6	839·4	1,691·2	6,235·2	16,560·5	3,805·0	6,821·1	27,186·6	293	187	988	1,468	8,310	9,778
3	8	19	2	18	46	66	151·3	230·8	259·3	641·4	606·8	1,198·2	1,332·6	3,137·6	11	99	344	454	5,837	6,291
4	23	22	8	88	145	241	893·7	6 118·4	2,262·4	9,274·5	4,363·0	52,229·8	12,733·4	69,326·2	77	382	687	1,146	8,858	10,004
5	27	9	5	23	29	57	611·8	326·2	203·6	1,141·6	3,561·1	2,142·5	1,064·2	6,767·8	40	88	86	214	3,772	3,986
6	40	4	3	23	39	65	255·8	165·0	196·6	617·4	1,160·5	731·1	896·7	2,788·3	14	77	196	287	3,829	4,116
7	10	5	2	9	24	35	426·8	74·9	129·1	630·8	2,173·1	354·4	624·4	3,151·9	32	17	76	125	1,988	2,113
8	1	15	4	19	30	53	297·5	221·7	231·6	750·8	1,228·2	1,212·5	1,033·6	3,474·3	22	145	122	289	4,061	4,350
9	21	11	4	14	51	69	459·0	111·5	722·3	1,292·8	2,325·9	496·5	3,378·5	6,200·9	59	70	409	538	4,069	4,607
10	23	8		5	14	19	—	27·2	48·2	75·4	—	116·5	184·9	301·4	—	17	104	121	1,784	1,905
11	27	15	20	33	163	216	4,139·9	817·4	641·1	5,598·4	17,866·0	3,350·7	7,531·3	28,746·0	251	194	756	1,201	4,361	5,562
12	7	4	—	3	8	11	—	78·0	44·3	122·3	—	341·2	213·5	554·7	—	10	71	81	1,441	1,522
Totals ..	217	62	74	278	810	1,162	11,841·1	9,254·7	7,012·1	28,107·9	54,090·1	67,012·2	37,616·8	158,719·1	843	1,318	4,083	6,244	51,692	57,936

TABLE No VIII

Shewing an Analysis of the Basins in each Main Drainage Area according to their Areas.

Number of Main Drainage Area.	Coast to which the Streams drain	Number of River Basins in the Main Drainage Area: Total	With Areas in sq miles ranging from: Over 1,000	500 to 999	100 to 499	50 to 99.	10 to 49	Under 10	Drainage Area in square miles: Total	In river basins within Area: Exceeding 1,000 sq miles.	Ranging from: 500 to 999 sq. miles	100 to 499 sq. miles.	50 to 99 sq. miles.	10 to 49 sq miles	Less than 10 sq miles	Number of Rivers in the Area.	Length in miles of the Main Streams
1	East	16	1	1	9	1	4		3,702	1,130	708	1 664	77	123	—	19	549
2	..	14	2	3	8	—	1	—	9 778	5,894	2,291	1 554	—	39	—	47	1,297
3	..	8	3	1	4	—	—	—	6,291	4,763	780	768		—	—	25	772
4	..	23	1	2	13	4	3		10,004	4,613	1,560	3 468	273	90	–	53	1,364
5	South	27		1	10	8	8	—	3,986	—	673	2 564	549	200	—	20	399
6	South & West	40	—	1	11	9	18	1	4,116	—	584	2 375	620	529	8	29	541
7	West	10	—	2	3	2	3		2,113		1,453	404	162	94	—	10	238
8	..	1	1	—	—	—	—	—	4,350	4,350	—		—	—	—	23	604
9	..	2	1	2	8	10	—	–	4,607	1,609	1,054	1,201	743	—	—	35	799
10	..	23	—	—	5	8	9	1	1,905	—	—	1,038	537	327	3	29	316
11	..	27	—	4	8	7	6	2	5,562	—	2,994	1,918	439	199	12	42	781
12	..	7	—	1	2	3	1	—	1,522	—	915	366	220	21	—	13	274
		217	9	18	81	52	53	4	57,936	22,359	12,992	17,320	3,620	1,622	23	344	7,934

TABLE No. IV.

SHEWING AN ANALYSIS OF RIVER BASINS ACCORDING TO THE DISTRIBUTION OF URBAN POPULATION.

Number of River Basins.	Range of population in thousands.		Aggregate area of the river basins in		Aggregate urban population in the River Basins in	
	Maximum Urban Population in any one Basin.	Minimum Urban Population in any one Basin.	Sq. miles.	Terms of the area of the whole country as unity.	Millions.	Terms the whole Urban Population as unity.
4	6,958	1,718	10,365	0·179	14·5	0·517
9	909	504	8,953	0·155	6·3	0·224
23	359	101	12,635	0·218	4·4	0·157
18	91	51	6,195	0·107	1·3	0·045
59	48	10	11,710	0·202	1·3	0·048
56	9	1	2,190	0·038	0·3	0·009

Discussion.

The **President,** in moving a vote of thanks to the author, said that they were indebted to him for an extremely interesting paper. The scheme which had been propounded was a bold one but, in the speaker's opinion it was not bolder than the urgent needs of the public demanded. Several points had been touched upon, perhaps broadly, but he was sure that they would all hope that the experience of gentlemen present would be brought out fully in the discussion. The paper was one which essentially lent itself to a good discussion.

The vote of thanks was carried by acclamation.

Mr. Easton Devonshire said that the paper was a very valuable contribution to a question which, with increasing activity, a great many engineers were studying at the present time, namely, the question of the conservation of the national water supply. But in some respects, he thought, the author had put the cart before the horse. On page 122 the author said : " Such an organisation should not, however, be created until an exact survey of the national water resources has been made, and a system of hydrographic records has been established, and Parliament has in its possession data such as that arising from the investigations undertaken by the Governments of the U.S.A.," and so on. He was very fully in agreement with that statement. With regard to the following paragraph, it seemed to him that the author could not have had in his mind at the time that he wrote the paper the fact that on an Order of Parliament of November last the Local Government Board issued circulars inviting information from all the water authorities of the country as to the powers under which they supplied water, the sources and the works of the water supply, and various other statistics, and also inviting from all the local authorities in England information as to how the needs of the population were supplied in the matter of water, whether piped or not. When the records were available the first step would be taken towards the solution of a very difficult problem. Some of the questions in the circulars had come under his notice as the acting Chairman of the Water Areas and Statistics Committee appointed by the Association of Water Engineers, and he was afraid that the form in which some of the questions were put was likely to bring in answers which would not give the information wanted.

With reference to district boards and river boards, he understood that in the author's scheme the functions of those boards would be very wide, and that the boards would be composed of local authorities to a great extent. The author said : " Both the district and river boards should be as fully representative as possible, not only of the local authorities but of all the con-

servancy interests, such as water supply, inland navigation, drainage, fishery and sub-surface waters " No doubt the nterests of the supplier of water in the conservancy of the water available was considerable, but in nine cases out of ten it was not his chief interest. His chief interest was to get as much water as he possibly could at the cheapest price, regardless of his neighbours. He (the speaker) was not quite sure how far the terms " district boards " and " river boards " differed as regards their functions from what were sometimes called " water boards." The expression " water board " had been interpreted variously by the various persons who used it. It had been supposed to include in some cases comparatively limited functions, such as the functions of a conservancy board, but in others it was intended to include the functions of distribution. What was needed first in the matter was an absolute distinction between the functions of conservancy and the functions of distribution, and he thought that if attempt were made to form boards, subject though they might be to one central organisation, whose interests were at all events as largely those of distribution as those of conservancy, the whole scheme for the conservation of the national water supply would be very much injured.

The Association of Water Engineers many years ago appointed a standing committee which was called the Water Boards Committee, a title now altered to Water Areas and Statistics Committee, and in November, 1900, that committee presented a report to the Association which might really have been destined to serve as a model for the report which had just been published by the Select Committee on Lord Desborough's Bill. Both of those reports referred to matters with which a water board, as a distributing body, had nothing whatever to do. They both referred to the principle of the conservancy of the water supply of the country, its protection from pollution and waste, and its proper allotment among the communities for whom nature intended it. The report of the Committee on Lord Desborough's Bill was a very remarkable one. The Bill itself proposed things which were not in accordance with the report. He thought that all water engineers owed Lord Desborough a debt of gratitude for having roused them up to give evidence on this most important subject, and as a result of that evidence having caused the Committee to publish such a very valuable report.

The question of local supervision of the national water resources was certainly a difficult one. The procedure followed or the schemes to be formulated should be on the lines of a central organisation, perhaps under the Local Government Board, who would have quasi-judicial powers for the protection of the national water supplies all over the country. The central body would not be represented in various parts of the country by district or river boards, as he understood the author, of the type

which he suggested, but by its own agents, scientists very often; because the thing must be worked by scientific men who were experts, and by paid and voluntary assistants whose duty it would be continuously to supply the central authority with records of the flow and level both of surface and of underground waters. Armed with that information, the central body would act, and could act as an advisory body to Parliament in case of Bills for water supply or to the Local Government Board in applications made locally, and their duty would be to show from the statistics they had obtained how far the needs of any particular district could be met in that district. It was quite clear that the area or the district which would supply the water to be used in particular cases would not be co-terminous with geographical administrative boundaries. It might be possible later on to evolve a scheme showing how the various local interests could be usefully united to form a board to control the waters in the geological districts which would be under consideration, but he feared that the interests of the majority of such a board would tend to bring about a decision to take the best and cheapest water for local needs regardless of the national interests involved.

The step which was preliminary to all the schemes had been taken by the issue of the circulars asking for returns. The next step would be the extending of the returns, the collating of them in an intelligent way so as to get the information which was really wanted with reference to the sources and quantity of the water available, and how much of it was used and how it was used, and upon that to form an organisation which should have powers first of all to make the hydrographic survey which the author rightly said was essential, and then to watch and report continuously upon the variations of flow and level, be it on the surface or underground of all waters in any particular district, and with that knowledge to advise Parliament or the Local Government Board as to whether an individual or a public body or a combination of public bodies should take a portion of the water within their own boundaries, or if that was insufficient, the water outside their boundaries and in the area of another conservancy board.

Mr. Percy Griffith said that he had intended to make a few general observations upon the subject of the paper, and, with the permission of the President, he would express his own views by reading an extract from the report of the Director of the United States Geological Survey for the year 1908. He thought when those present heard the remarks they would agree that they were so appropriate to the position of affairs with regard to water supply in this country that he need hardly apologise for quoting them. The report said: "The idea that water is our most valuable resource, as it is the most active agent in changing or

modifying or limiting all those other resources which are so necessary to commercial and economic development is by no means new. Prominent engineers in this country have long recognised it, and have advocated the extension of the Government investigations and water resources, and in European countries centuries of experience have demonstrated what water investigations are necessary to a continuance of prosperity. . . Legislative provision for the investigation of water resources is one of the most important of those necessary acts that may be called anticipatory. The immediate value or application of the results of such investigations is outweighed by their prospective value, a value which will become greater as the passage of years brings increased population and consequent enlarged demands on these resources." He (Mr. Griffith) thought the writer of that report could hardly have expressed the position of affairs in this country more exactly.

It must be admitted that the subject was too complex to be settled arbitrarily by any party or by any conjunction of parties interested. The subject was one of national interest. It affected all classes of the community, and in particular with regard to the actual water supply itself there were a great many interests involved beyond the elementary one of the domestic supply of the population.

The United States had gone much farther in the direction indicated by the author than engineers in England had attempted to go. Until recently there had not even been a start made in the direction of doing that which water engineers for many years past had admitted was necessary.

He would support very cordially what Mr. Devonshire had said with regard to the procedure which was essential for achieving the object desired. It would be very objectionable to create a large number of local and district authorities to deal with the question. He hoped that the first preliminary step having been taken by Parliament in ordering a return of all the available sources of water throughout the country, they would arrive at something like a basis for the complete statistical information which was wanting in this country. It was quite clear from the forms which he had seen that the information asked for was not by any means complete, but he did feel certain that the collection of the information now asked for would be a valuable indication of the further supplementary and qualifying information which would be necessary to make the returns of practical value. He was content to leave to the Local Government Board the onus of discovering in what respects amplification would be necessary, and no doubt the Association of Water Engineers would have something to say on this point, and would be very willing to offer their services in the matter.

Speaking generally upon the subject he thought that water

engineers must not lose sight of the main object which ought to be before them throughout the whole of the discussion of the subject. He suggested that this should be strictly limited to three things: Firstly, to ascertaining the resources as regards water supply; secondly, the actual requirements; in which connection he cordially admitted the author's claim that the domestic supply was not the only demand made upon the available water supplies, and that all branches of trade and industry which required water must be at the same time fully considered. The investigation must be made as comprehensive as possible. The third point was the adjustment of the available resources to the requirements both existing and prospective. Of course, that was stating a very complex problem in a very few words, and he did not for a moment suggest that the problem was a simple one. He did, however, urge that unless water engineers concentrated their minds upon a simple statement of the object in view they would be easily diverted into a mass of confusing details which would be very liable to leave them worse off at the end of the investigation than they were at the beginning.

There were two important questions which Mr. Devonshire had lightly touched upon which he should like to emphasise. One was that in adjusting the resources to the requirements great attention must be paid to the all-important question of waste, in which must be included the most economical utilisation of the water generally. That involved rather more than was understood by the word "waste." He thought he might amplify the point as to the application of water in the best possible way for all possible purposes, which would, of course, include waste at the source as well as waste on the part of the consumer. The Local Government Board had indicated, by the form of the enquiries which they had sent out, their intention of investigating the question as to how far the available resources were at the present time utilised. It was obvious that in all those cases where large quantities of water were allowed to flow to waste from impounding reservoirs that this water was not being economically utilised.

But while that question was relatively elementary as regards surface supplies, the question of underground water was a much more complex problem. He thought that they would be compelled to abandon any attempt to allocate on a geographical basis the areas of control with regard to underground water. The underground supplies did not travel, like the overground supplies, in defined channels, and could only be traced and measured at particular points. The conditions varied considerably even in places only a few miles apart. Of course, the water from a particular outcrop was available over a very large area if one included the factor of pumping from a considerable depth, but on that point data were wanting. He had been interested in a somewhat costly experiment as regards the depths at which it

was possible to obtain satisfactory water supplies. With a source never previously questioned and never found defective (the new red sandstone), water tapped at a depth of 750ft. was pumped from a level of 300ft. below the surface with perfectly satisfactory results. The same source was tapped a few miles away at a depth of 1,500ft., but it was found that the water had acquired hardness and other unsatisfactory characteristics which made it absolutely unfit for use for domestic supply, and that supply had to be abandoned. That proved that there was a limit to the depth at which underground water of a satisfactory character could be obtained. Such experiment involved the expenditure of very large sums of money, and it was cut of the question to suggest that similar experiments could be made often or all over the country.

He could support the author very strongly in his statement that existing methods of collecting data with regard to underground water were very faulty. This was not because of any want of good will on the part of those who assisted. but for the want of some common form in which the data were to be collected.

The recording of the levels of wells at different times appeared to be a very elementary matter, but as soon as one began to carry it out on a systematic basis and try to obtain statistics which would be really useful it was found that it was a very complicated problem indeed, and that the system must be codified and made uniform throughout the country if the records were to be reliable and effectively useful for the purposes in view.

There was one important matter which had not been mentioned in the paper. He thought that all water authorities were interested in obtaining a consolidation of the general water works law. That point, of course, covered the very important question which he had just referred to, namely, that of underground water and its many complexities. With regard to the whole of our water works legislation, he suggested that attention should be given to the subject in order to simplify the present complex state of affairs, not only with the idea of making it easier for those interested to understand the practical effect of the law as it stood (although that would be useful), but rather with a view of rendering more economical the processes which were involved in securing proper water supplies throughout the country. The problem with regard to large towns had been very largely solved, sometimes over-solved, at the expense of the smaller places, but the procedure involved in obtaining sanction to water supplies for small towns was at present needlessly costly, having regard to the financial capacities of the communities which had to be dealt with.

Mr. William Whitaker said that he was glad that there was general agreement with what the author said to the effect that

the suggested organisation should not be created until a survey of the national water resources had been made. It was necessary before any attempt to pass legislation was made that the facts should be collected. No legislation which was not based on facts would be of any value and at the present time some of the facts had not been obtained. The Local Government Board had taken several steps in view not only of getting the returns, but of using them. Amongst other things they had appointed a geologist on their staff.

The splendid work of the United States had been referred to, but water engineers in this country must take great care how they in any way used that work if they attempted to compare it with what was done here. It must be remembered that the United States was a large country, and that this was a small one, and what might do in the one might not do in the other. The United States was also a country of federated states with a central government apart from the others, and therefore their method of proceeding would be different from that of this country. Again, it would be seen that a large amount of the expenditure in the United States was for irrigation work. Irrigation work was a matter of practically no moment or of comparatively small moment in this country. He believed that comparatively little water was used for irrigation purposes in most parts of England. The use of water for irrigation purposes, inland navigation, and a variety of other things here must be kept apart from the question of the supply of water for use in houses, factories, or what not.

Whether or not a board could look after all matters connected with water supply he did not know, but it was possible that there might be some difficulty about it. The author truly said that there had been an enormous amount of data collected with regard to water, but that it was scattered and imperfect. He (the speaker) would like to know what work of man was not imperfect. He had had a great deal to do with the matter, and he knew what the result of attempting to attain perfection would be. If he had information he always thought that it was better to get rid of it, and publish it, imperfect as it might be, sooner than keep it back to await perfection.

He was glad to say that the work of codifying and improving was being specially done in one particular by the Geological Survey, that is for London, a somewhat indefinite district, but the Geological Survey used the word in a very broad sense. They were collecting together all the accounts of wells, and they had published a vast number. To the published ones they were adding a great many particulars as to the level of the well and the level of the water, and, where they could obtain them, particulars of the variations in the level. He believed that shortly a memoir on the London wells would be published, which, whilst not giving the details of all those that had been published, would give this

further information in the form which was required for any engineering enquiry. As Mr. Griffith had said, it seemed a very easy matter to do these things, but it was not so. Several hours' work might result in a line of print.

When the author spoke of geological structure, he (the speaker) got a little in doubt. Happening to be a geologist, he doubted the goodness of the available information, and he doubted the possibility under present circumstances of getting exact information in many districts. He said this because he knew the defects in geological information. The areas given in the paper must, of course, be taken as approximate only, and he was sure that the author would agree with him in this. There was a large area of the kingdom which had not been mapped in such detail as was now used. There were areas which were coloured one thing, but which were known to be another. The reason was that they were mapped on the old geological principle of mapping all the great series of sedimentary forms except the top one of all, the Drift, which varied in its character in different places, so that without a detailed map one could hardly tell where he was. In the South of England the work was largely done, but in parts of the Midlands and elsewhere a great deal of additional work was required.

He cautioned the meeting against geologists if they attempted to say that they could tell the areas of permeable strata and impermeable strata in some parts of the country.

There was one matter which had barely been touched upon. That was that in any enquiry like the present it was not sufficient to deal with public supplies only. If private supplies were not thought of in some cases tremendous injustice would be done to the public ones. He believed that there were a good many districts where the private supplies were stronger than the public ones. Therefore any legislation must depend largely upon what could be learned of the private supplies. He was very thankful that in all his work in connection with underground water he never troubled as to whether wells were for public supplies or for private supplies. He published all that he could, and from the time when the Geological Survey started its work no difference had been made between public and private supplies. There was a splendid illustration of what he was saying just on the other side of the Thames, in the largest public well-supply in the world, that which belonged to the Kent Company and was now part of the Metropolitan Water Board. It had furnished up to something like 20,000,000 gallons a day of public supply. When things were investigated thoroughly it was found that despite that being, as it then was, the biggest public well-supply in the country, the private supplies in that particular district went appreciably higher. How ridiculous it would be in such an area to attempt to introduce any rules and regulations without

taking into account the private supplies. That was, perhaps, an exceptional case. The area was one in which there were a great number of very large factories, one of the essentials of which was a very large amount of water.

There was another matter which he hoped would be kept very much to the front, and which, being a little connected with sanitary science, he thought of great importance. It was not the mere getting of water and the getting of good water which was required, but taking care that the water was kept good, taking care that it was not polluted ; and sometimes going further and getting rid of pollution which had existed perhaps for some time. It was little good for a town to get a good water supply if there was a likelihood in a few years of some abomination coming round about where its supply was got and spoiling the water. The matter was a very serious one. Any enquiry into water supplies must not deal simply with where and how to get the largest quantity of the best possible water, but also with how, when it was obtained, care could be taken to insure that it was never spoilt.

Mr. E. J. Silcock said that the paper was a remarkable one in the wealth of statistics and tables with which it was illustrated. But he was bound to say that to some extent their precise bearing upon the main subject of the paper was not strikingly obvious.

He took it that the author's object was to advocate water boards on the particular lines which he indicated, namely, the establishment of a hydrographic department, district boards, and river boards. So far as the tables went, the only way in which they really affected that question was in emphasising the great diversity of circumstances in the various drainage districts in this country. He was afraid that the author's scheme would result in a great deal too much supervision. The twelve districts which he had mapped out as being under the control of district boards would, he thought, be good for the general supervision of the country, but he (the speaker) could not help thinking that the establishment, in each of those twelve district boards, of large numbers of river boards would be carrying the thing a little too far. He viewed with some alarm the multiplication of officials and the officialism which such a thing would involve. Recent legislation seemed always to be in that direction. He was afraid that soon the country would consist very largely of officials, and the people who were not officials would be in the minority.

Although they would all agree with the general principle that there should be a comprehensive view taken of the water supplies of the country, yet he thought that there was a possibility of going to greater lengths in the conservation of the purity of water than the results would justify. His experience led him

to that conclusion because he was familiar with the district drained by the four worst rivers in the country, viz., the Aire, the Calder, the Mersey, and the Irwell. There was no doubt that those rivers in the past had been in a very bad state, and they might possibly have been at certain periods of the year a menace to the health of the people in the towns through which they flowed. Therefore, there was room for improvement, but he did not think that the most sanguine person would ever suggest that these rivers could be purified to such an extent that the water could be used for human consumption ; and he did not think they were justified in going beyond the point at which they would escape damaging the health of the people in the neighbourhood of the rivers. The expenditure which towns and private individuals and manufacturers were being called upon to incur in the purification of sewage and trade effluents was very heavy, and it had to be borne in mind that after all this expenditure was a tax upon the industrial part of the community, and the expenditure might go on until our industries were taxed altogether out of existence. It seemed to him that there were certain rivers which they ought to make up their minds to regard as sewers, and that they should never attempt to introduce there such systems of sewage purification and such a high standard of purity as would be required in the cases of other rivers which were situated in totally different surroundings, from which public water supplies were likely to be taken. That was a view of the case which should not be lost sight of, and it had some bearing upon the question of representation on the proposed boards. He gathered that the author was concerned because certain urban sanitary authorities would not be represented on the river boards, but he was not quite sure that it was a desirable thing that those urban authorities should be so represented. In the first instance, he did not think that the boards should be too big. If all the sanitary authorities were represented on the district and river boards, there might be a certain amount of log-rolling. As a general rule the personnel of the county councils and the county boroughs consisted of some of the best business men in the country, and he thought that it was quite possible if not likely that smaller district boards appointed by culling the best men out of those elected bodies would produce better tribunals to determine questions of river pollution than larger bodies composed of single representatives from separate smaller bodies which themselves probably would not contain such good business men. The question of expense would, of course, determine how much should be done in the matter of survey, but he was inclined to think that the author's views as to what the expense of survey was going to be were very much on the low side. Looking at the details given in the paper, he felt pretty sure that work of a very extensive character could not be carried out for anything like the money

suggested in the paper as having been spent in other places. For instance, he saw that in the United States in 1881 the sum of £197 was spent in travelling expenses. It was obvious that that was not more than would be spent by one person going about a fairly large district. He was afraid that the item for travelling expenses would have to be very largely increased.

Dr. S. Rideal said that the matter seemed to him one which required investigation, but it was not so much the duty of the expert to inquire what should be done as the duty of the lawyer to work out a scheme which would put matters in a better position. He observed last week that Mr. Balfour Browne had views on this subject, and a man of his experience would probably be the best man to form an opinion as to what legal machinery was necessary for getting a practical scheme throughout England. Mr. Balfour Browne's views upon this paper would afford very great assistance.

He observed that the different authorities which were given in Table 1 of the Appendix as dealing with water went back to very early times and were very numerous, but the last two Government Departments which had anything to do with the subject were the Development Commissioners of the 1909 Budget Bill and the Treasury. After all, it might be that from these two sources the public might reasonably expect to get help in the matter. He did not think that because the Local Government Board was already in existence, because it was taking a little greater interest in water purification than it had in the past, that there was any reason for expecting it to deal with the whole subject better or as soon as a new authority. Even when a Royal Commission, brought out under the ægis of the Local Government Board, presented its report, no further steps were taken, and many Commissions on these and similar subjects had been in existence within the last twenty or thirty years and no action taken. Therefore, he hoped that the Development Commissioners might be able to do something, and, of course, if the Treasury through them took an interest in the water supply of the country, they might see a practical solution of the problem within a few years.

Mr. H. Alfred Roechling said that he had been struck with the amount of labour which the author had devoted to going through official returns for the purpose of writing his paper. He had read two papers written by the author for other institutions, and he had noticed the careful way in which the author had dealt with his subjects. The subject of the national control of our water supplies was a very big one; and they had been reminded by Mr. Whitaker that they should not deal with public supplies alone, but with private ones as well. The meeting could only

discuss the question in an academic sense, and he should deprecate dealing with a lot of detail at this stage. They ought not to split up their forces in dealing with detail, but should concentrate them on the main object in order to get Parliament to pass some measure of national control of water supplies. Those engineers who had had to deal with Parliament in various ways knew how extremely difficult it was to get anything through Parliament. There had been a Sewage Commission sitting since 1898, which had cost the country something like £80,000, but he thought he was right in saying that so far not a single legislative enactment had been added to our statute law as a consequence. When they considered the enormous amount of work which rested upon Mr. Burns's shoulders now it would be seen to be absolutely necessary that they should not split up their forces upon a lot of detail, but should concentrate in one effort to get him—and members of Parliament generally—to see the necessity of having some such protection. The Civil Service estimates had increased enormously, and they were now larger by about 50 per cent than they were a few years ago. They had also been reminded by great experts in finance that the wealth of the country was not growing at the same rate as its expenditure, so that it behoved people to go very warily before they tried to get Parliament to embark on any new measure. He would once more urge upon all those present not to split up their forces, but to go forward unitedly on one main object, namely, the national protection of water supplies.

Mr. D. F. Worger associated himself with all that had been said by the former speakers in reference to the value of the paper. The author appeared to have summarised in a very able manner a vast amount of detail, the work of obtaining which must have been enormous. The author quite appreciated that the creation of the new department, a hydrographic board under a Minister of Water Supply, was likely to take some time to realise, and he proposed and had referred to the necessity of some organisation being created to get further information upon this most important subject. From the information given in the paper as to the cost of such appropriations it evidently was a very small matter from a financial point of view ; but the question of who would undertake the getting together of the information appeared to be much more important. Personally, he had not been connected so much with the conservation of water in its natural state as with its distribution, and yet one could not read the paper without desiring to know a good deal more.

The author gave the proportion of urban to rural population throughout England, and showed what a large proportion the urban population bore towards the rural in the districts to which he referred, namely, 78·8%. Then, again, as regards rateable

value, the paper showed under the head "Number of River Basins," that with the urban area of the whole country as unity London practically was 0·37 of the rateable value of the whole, so that London was by far the largest unit in all the figures given.

Again, the author referred to the capital invested in hydraulic works. In dealing with his 54%, which amounted to £135,000,000 of capital in water supply works, the author estimated under "County Borough and Borough Councils" 57·6 millions, and under "Twenty-two Joint Boards" 50·3 millions. He (the speaker) could not quite reconcile either of those figures, because he took it that in one or other of them was included the Metropolitan Water Board's capital, which alone was £49,000,000, and therefore he could hardly see if it was in the first "County Borough and Borough Councils" where the money was that had provided the water supplies to, say, Manchester, Liverpool, and Birmingham, as £8,000,000 would not cover them, and if it was in the other item (Joint Boards) he did not think that the other 21 Joint Boards could be made up in the one million left after the £49,000,000 of the London Water Board was taken out.

The author alluded again in his concluding paragraph to the necessity for data, but all present knew what that meant. Everyone's business was no one's business. He (the speaker) could not help thinking, from consideration of the figures which he had mentioned and of those in Table IV., where clearly London must be referred to as the "maximum" urban population in any one basin, the 6,958,000 that formed London was a very large proportion of the whole. Again, it was further intensified in Table VII., where, under "Number of Main Drainage Area" at 4, the figure for the population was given as 9,274,500, and the rateable value was given at £69,000,000, as against the next highest of £5,500,000 and £28,000,000 respectively. The main drainage area showed, again, what a preponderance there was in the case of London. If that was the case, should not London form some body to obtain the data and information which everyone seemed to admit was what was so urgently needed. Whether it was to be the Local Government Board, the Metropolitan Water Board, or any committee of, say, the British Waterworks Engineers, or anything of that sort, it did appear to him that it was to London that they had to look in the future as the medium for getting the very valuable information which was required.

As far as the author's suggested watersheds were concerned, there was one point which seemed a little peculiar. It had relation to the figures given in Table VII., where Watershed 4 was so enormous, especially as compared with its neighbour 3. Would it not have been advisable for the author to retain the boundary shown, not on his own scheme, but on Mr. de Rance's

scheme, so far as the portion of Norfolk and Suffolk was concerned It struck him that though it might be perfectly true that the watershed strictly comprised those portions, it would not be difficult to leave them out and augment the one at the expense of the other, the very large one.

With regard to preventing waste of water (he should rather call it the misuse of water) he thought that where the question of water was such an important one as it was in England it could be conserved, if one might so say, in its later stages, to a very great extent in distribution. He had had an opportunity during the last three or four years of paying special attention to that matter, and he had been able to reduce the supply in the district over which he had control by 4·6 gallons per head per day, amounting in all to nearly 9,000,000 gallons a day simply by not only giving attention to waste, but to what he more particularly referred to as the misuse of water. Still a large amount of work had to be done, and there was need of extreme care to see that people were not allowed to throw water away recklessly as if of no value whatever.

Mr. Shenton said that if he was not mistaken the Committee on the Water Supplies Bill strongly advised that steps should be taken to form some organisation to collect information with regard to water supplies all over the country. Such an organisation should now be created. Surely the first step towards legislation was to constitute an authority to do this work of gathering information. If the Local Government Board were sending round a list of questions to all the authorities they would no doubt get a vast amount of information sent in, but it would be quite useless unless it was put together in a useful form, and the putting of it together would be an enormous work for the Local Government Board. He supposed that at the best it would appear in some large Blue Book, which would present a mass of tables, and which would be published in the course of years. Unless other steps were taken everything must stand still until they had the information gathered by the Board printed and tabulated, which, when obtained, would be incomplete. It seemed as if the first step must be to form some authority to take the matter of the hydrographical survey over and deal with it. The way in which the Geological Survey did similar work, taking county by county and publishing a volume dealing with the water supply, seemed to be the sort of thing that was required. At any rate, the publications of the Geological Survey were the only material which had any sort of official origin and was of any use to water engineers at present. He suggested that it was of vital importance that the present action of the Local Government Board should not be regarded as fulfilling the requirements of the Committee on Water Supplies. It should not be allowed to lead

to another period of inaction. The information gained might be of assistance to the new organisation when formed, but the immediate formation of that organisation was required.

Mr. Wynne-Roberts said that the author was to be complimented upon the statistics which he had put before the Society and upon the enormous amount of labour which he had devoted to the paper. The subject dealt with was certainly of national importance. He spoke at a meeting at the Sanitary Institute some two years ago in a minority against the proposition to form a multiplicity of water boards, and he ventured then to suggest that with the multiplicity of authorities, not only for water but for various other matters, there would be far too many authorities in the country to carry out the work in a proper and economical way. The suggestion of Mr. Easton Devonshire struck him as being a most practical way of at least starting the proposed organisation.

The problem was not so simple as it might appear on paper. There would be a great diversity of interests involved in the investigation. There was not only water supply by public authorities for towns, but water supply for a variety of purposes. If there was going to be an elected water board, there would certainly be internal friction through having representatives of the different authorities on the board, some of whom would resent restrictions and expenditure imposed by another section of the board. It seemed to him that Mr. Devonshire's suggestion solved the problem, at any rate, for the time being. There ought to be an official appointed, a provincial engineer or a provincial geologist, or whatever one liked to suggest, who would have charge of investigation in water basins, and, where necessary, have the assistance of representatives of local interests.

The author had drawn attention to the hydrographical investigations conducted in America, in the Colonies, in India, and elsewhere. He would like to suggest that the statements given should be taken with a certain amount of reservation. He happened to know something about the investigation which had been conducted in South Africa. In the Transvaal there were hydrographical investigations in existence, but every one of them was for the purposes of irrigation. Even so, they were not carried out anything like so completely as they would have to be in this country. For instance, the rainfall records were very sparse in that country. The river gauging was exceedingly difficult, and not only was it difficult, but it involved an enormous amount of labour, and, as would be seen by reference to the cost in the Transvaal, it was a very expensive item.

In the United States the investigations were for the purposes of irrigation. The work done by American engineers was certainly excellent as far as it had gone, but it did not give any indication of the probable cost of an investigation in this country.

Italy would give a better indication because the investigations were carried out much more fully in Italy and in parts of France.

In India the investigations were for the purposes of irrigation. It would be seen at once that, apart from Italy, the countries named by the author did not afford a guide as to the probable cost of collecting data here.

There was no doubt need for reform, and also there was need for retrenchment, and there was no need for increased expenditure without having, at any rate, full returns. One advantage of having an investigation would be the economical development of the water supply of the various watersheds. That, of course, they all desired to see. If the suggestion thrown out by Mr. Easton Devonshire was acted upon, no doubt some good would be done.

Mr. Philip Parker said that the small attention paid in the discussion to the undoubted necessity for gauging the various rivers referred to and publishing the results had greatly impressed him. He saw many gentlemen present who possessed information of the character required, and was well aware that some of these gentlemen had often published results referring to rivers and streams outside England. In England, however, he believed the only river of which accessible gauging records existed was the Thames. It might be that others were published, but he had been unable to discover them.

Having had to do with gauging work in America, India, and Australia, he could assure the meeting that the public never granted money unless it received statistics, and the easiest method to get a grant was to publish the available statistics first. Gauging was not a costly matter. In the years when 700 gauge stations existed in the United States, over 400 were on streams of about the size of British rivers, and were intended for town water supply records. The cost of making the records of such a station was about £10 per year. The costly work in America was in connection with irrigation investigations. Another thing that seemed to have been missed was the fact that gauging work was cumulative. It required a skilled engineer to obtain the relation between the gauge height and the volume discharged. But once the river was gauged in this sense the thing was done for ever except in cases where the bed shifted, which he believed did not occur in England. He believed that any engineer who would determine the discharge curve of a British river would be able to collect records of the heights of the water surface which would permit him to obtain the daily discharge for many years back.

The **President** requested the author to reply briefly as an opportunity would be given to him to extend his reply before it was published in the JOURNAL.

Reply.

Mr. Wiseman, in commencing, said that if he was to reply shortly he should, of course, be unable to refer to all the many points which had been raised.

With regard to the Order mentioned by Mr. Easton Devonshire, he was well acquainted with it, and he quoted it in full in a paper which he sent to Mr. Devonshire two months previously, but which he supposed Mr. Devonshire had not had time to read. Mr. Devonshire had asked whether it was worth while to go to the expense of getting information. He would put it in this way. They must balance the cost of the various promotions in the committee rooms against the cost of the survey, and in all probability it would come out with the survey on the right side.

Without the basin boards it would never be known what the local wants and difficulties and essentials were. If there was a basin board, with all the different interests represented, the different needs which at present came up to Westminster and met with a lot of opposition and were in many cases unsuccessful would be thrashed out by the local basin board. Englishmen always started with big ideas of their own, and they wanted to see their own hands prevail, but when they found that there were five or six other men with equally strong hands they arrived at some compromise, in which they got the best they could. The local committees of the river boards would, on any promotion, arrive at some general compromise, and then it would come up to Westminster backed by the basin board in a stronger form and much more cheaply than was the case at present. That was, roughly, his idea as regards the basin boards. He did not contemplate an authority which would always be upsetting everybody, and he did not suggest bodies similar to the three or four existing river boards, which were mainly rivers pollution prevention boards. Judging from the accounts one read in the "Yorkshire Post" and other papers, their path was not an easy one, neither was that of the Local Government Board, with regard to which they appeared as troublesome offspring, judging by the number of questions with reference to them which Mr. John Burns was asked in the House of Commons and had to answer somehow or other.

With regard to Mr. Silcock's query, the tables were intended to illustrate the uselessness of trying to create new river authorities out of the old or existing administrative authorities, since they would not then be truly representative of all the water interests of the area, and would in some cases be particularly unwieldy bodies. He was by no means anxious, and he had not stated that every urban district should have a representative, but he thought that these and all other authorities with any real interest in conservancy should have representation, which was quite a different thing.

Returning to the matter of the Order, he would remind the meeting that the point had already been answered by other speakers. The return would only get at what the water companies and the water authorities were taking. The quantity the private individual was taking was very much larger.

A case had been quoted by Mr. Whittaker with regard to the Kent Water Company, which had been worked out by Mr. Clayton Beadle. There was a better case and an older case, namely, the case of Liverpool in 1892, quoted by the author in 1909 in his paper on "The Increase in the National Consumption of Water." The engineer of that authority wanted to know the exact amount of water being used in the district. On making a very exact census he found that, neglecting the small users of water, the small traders who were supplied with water unmetered as domestic water, 21% of the total trade consumption was supplied from the Corporation mains, 30% was drawn from wells, and the rest from river and canal; and that when they came to add up all the quantity of water used in a year for trade, it came out to be a bigger quantity than that going through the Corporation mains for domestic and trade purposes.

Another point. In the making of a ton of paper manufacturers used a great quantity of water, which varied according to the quality of the paper. Banknote paper required most and cheap newspaper least. From 10,000 to 200,000 gallons of water was used for every ton of paper made; with an annual output of about 900,000 tons of paper one could imagine that the paper trade alone would put several water companies in the shade for consumption. An express locomotive would use 35 gallons of water per train-mile on the level track. On a stiff climb the amount would reach 41 or 42 gallons per train-mile. If they looked up the figures they would be surprised to learn that the consumption of water for the total train mileage was running up to about the annual consumption of over one and a half million people at 25 gallons a head a day. But that was not the whole railway consumption; there was the water used in steel works, engine sheds, carriage sheds, stations, cottages and various other places. The consumption of a railway company would be about double that due to its train mileage consumption. The result was that instead of 40 gallons per train-mile it could be put at 80 gallons per train-mile, and that would be about right, and on a train mileage such as that of 1909 the year's consumption would amount to 28,192,000,000 gallons. There was, further, the consumption of breweries and other trade works.

Several speakers had referred to the fact that some of the foreign and Colonial states which had instituted systematic water administration and investigation had done so because they were interested in the development of irrigation. It did not matter what their particular need or activity was, the only

important fact was they wanted the water, and they systematically measured and developed it. In every country and in every local basin in a country there was a particular need. In a Yorkshire basin the particular need was not water supply, in some basins the water was pure enough, it was not wanted for water supply, and it was a mere question of fisheries. Just in the same way in each foreign country one necessity cropped up above all others. In Italy the great thing needed was power. In India, Australia, South Africa, and the U.S.A. the great thing was irrigation. In Germany and Holland water was required for navigation.

In this country the great problem was keeping the water clean and bringing it into the towns for supply. Some of these other countries were doing such a vast amount of good work that if engineers only tried to build up a scheme from what they were doing a very fair start would be made.

The control of underground water had been mentioned by Mr. Griffith. He did not think that anyone who knew a scrap about underground water would ever think that he was going to control it or administer it by basin boards. Underground water was passing in different directions and under conditions which no basin board could control. He was not bothering about basin boards at all. What was wanted was information. He suggested in the paper the creation of basin boards and main drainage boards, but he also said that, before all this organisation came into existence, a survey would have to be established.

As to the American Geological Survey, which had been referred to by Mr. Whitaker, it was not comparable to our own Geological Survey. Our own Geological Survey was done by geologists, who had done more to build up English geological science than any other body. But the American Geological Survey was done by a combination of experts, many of whom were geologists, but there were also surveyors, engineers, chemists, etc., who made researches into cement, calorific value of fuels, and a host of other things; they were also responsible for the topography and the contours, which the Geological Survey in England left to the Ordnance Survey. Therefore, it was not correct to compare the American Geological Survey with the Geological Survey here.

Then Mr. Whitaker had grumbled at his (the author's) estimates of geological structure. He was quite aware of the splendid work which Mr. Whitaker had done in mapping the Drift, and he was quite aware that the solid geology maps did not convey a proper impression of the surface formations, and that some of the old maps were not accurate. He had found that out for himself. But he had taken a large-scale map on which the Drift could not have been shown even if it had been mapped. He had not the time to planimeter each of the 360 1in. maps and

take out each piece of Drift which had been mapped, and he did not know, with the complexity of clay capping gravel and vice versa, that he would have been any nearer the truth even if he had ; but he had taken a very large-scale map, and he had taken a couple of hundred records or more, and from those he had arrived at a fair approximation. Mr. Whitaker would notice if he referred to the tables that 00 was left in the tens and units places. He felt that he was getting some figure to go on, and that he was using Mr. Whitaker's principle of making the best of a fairly bad state of things in the way of data.

As to London, he could not quite settle the point which had been raised without looking up all his notes ; but he could assure Mr. Worger that the figures did not exist in the county boroughs, but that they existed in the joint boards. If the figure in the paper was wrong he would correct it. (On reference to his notes the author finds that the figure for joint boards should be 62·3 millions in place of that given, which would increase the total to £260,000,000, and alter the percentages given to a slight extent.)

Mr. Shenton had asked which was the body which was going to start the thing. He thought that if the Local Government Board or the Development Commissioners would call for a few surveyors and a few geologists they would be able to find them without any great effort. The Local Government Board Returns would not provide the information which was required. First of all, with the best intentions, some people would misunderstand even so plain a thing as the census paper ; then, unfortunately, there were a few people who seemed to think that if they gave away the little information which they possessed they would be failing to do their duty as British citizens, and when these came to fill up the forms they would not do their best to give all the information which was wanted. He was afraid that if the returns were going to leave out the trade consumption they would not help much towards the knowledge as to how the water resources of the country were being drawn upon, and, finally, a study of the circular left one in doubt as to whether all the points had been covered.

With reference to what Mr. Wynne-Roberts had said about Italy, he (the author) might say that he had a big library of pamphlets of one sort and another on this question of water administration. At the beginning of the present year he read a paper which would have easily gone to about four times its ultimate size, and as it was he was afraid the Secretary of the Society was somewhat horrified at its length, although it had been cut down three times before being sent in. In this paper he had tried to touch on all the varied aspects of conservancy, but he could not very well deal with all this foreign matter in every paper in which he mentioned conservancy. Long ago—the records would go back into the Middle Ages—different States

of the Italian peninsula had set to work to find out the water resources of their localities, and they had done so wonderfully well, and what was more to the point, cheaply.

The remarks recalled that only the other day he had received a report sent to him by a friend of his who had just finished a lengthy investigation by a commission of three for the commune of Milan. If a few experts such as these three would throw their hearts into the work much good work would soon be done at a comparatively trifling expense.

It had been stated by Mr. Parker that the only river of which there were any gaugings was the Thames, but he could assure him that there were a few other rivers up and down the country as to which information might be got from secretaries and clerks and so on. If asked, he could name a good half-dozen. He was afraid that what Mr. Parker said with reference to the cost of the American gauges was misleading. To drive a gauge post into a river, to survey the river a bit above and below, work out a cross section, use a Kutter's formula, tell a railway man to come and look at the post weekly and pay him half a crown, would probably cost no more than £10 a year in this country, but we wanted something a little better than that.

Mr. Parker said that he was referring to maintenance.

Mr. Wiseman (continuing) said that one speaker had quarrelled with the figure of £197 for travelling expenses. That did not really represent travelling expenses. All the officers of the American Survey Staff were allowed to travel free over most of the railroads, and the item of £197 represented the occasional travelling expenses of a few labourers. There was the warmest spirit of co-operation throughout the whole of the U.S.A. between the Survey and kindred organisations. If the reports were read it would be found that engineers were pleased to give information and there was not in America that spirit of reserve which was found amongst some engineers in this country. If a few of the younger engineers would throw their hearts into the work, and not consider the salary attached to the work, a lot of information would be obtained at a very small cost.

1st *May*, 1911.

F. G. BLOYD, President, in the Chair.

THE PROTECTION OF WATER SUPPLIES.

By H. C. H. Shenton.

[vice-president.]

The protection of the water supplies of this country is a matter of growing importance, and the difficulty of arriving at a just conclusion as to the necessity of adopting any given methods of protection, either generally or in a particular case, is a matter which is not easily decided. If a polluted supply invariably produced obvious disease ; if water once polluted remained so for any given length of time ; if the chemist's analysis demonstrated the existence of elements or compounds poisonous in themselves ; if the bacteriologist could prove to a certainty the presence or entire absence of harmful organisms, or if the microscopical examination could give clear proof that any given water would or would not cause ill-effects, the case would be simple. The case, however, is by no means simple. There are many instances of persons consuming badly polluted water during long periods without any recorded ill-effect, while in other cases the same pollution, or less, appears to have produced disease. It is by no means clear that pollution with crude sewage is necessarily dangerous. It does not follow that disease germs are necessarily present in such a case, though the probability of the presence of such germs is considerable.

Dr. Somerville, in a paper read recently before the Society of Engineers, stated that " In the fresh sewage of a large town, the organisms of typhoid, dysentery and other intestinal diseases are rarely absent " ; that B. coli, B. enteritidis sporogones and streptococci being constant in sewage were known as sewage indicators, but that certain anærobic sporing organisms were also very constant, and were capable of producing disease. Also that the ordinarily accepted water-borne diseases were not the only danger to be considered with regard to water polluted with domestic sewage, but " that with the progress of civilisation and the centralisation of man in cities, there is a corresponding increase in chronic infections of the digestive tract due to polluted water." In short, it is to be gathered that Dr. Somerville does not regard the coli test for water as being sufficient. Similarly, Dr. Thresh, as reported, has gone so far as to say that if all waters were sterilised, many diseases which are not located as being due to water contamination would mate-

rially decrease. This statement was made before the Committee of the House of Lords on the Cambridge Water Supply, and again a similar statement was made by him in a speech before the Sewage Works Managers. He is evidently of opinion that water may contain many harmful organisms besides the typhoid or cholera bacillus, and that it is quite probable that impure water is to blame for many minor illnesses, owing to the presence of organisms as yet undetected or undefined.

Professor T. A. Starkey, at the Leeds Health Congress, evidently regarded the bacillus coli as being in itself dangerous to health. He was of opinion that the typhoid germ is the most virulent member of the coli family. He stated very clearly that, in his opinion, the ordinary standard was wrong when it condemned water containing coli in 1 cubic centimetre and passed water if coli were absent from 10 cubic centimetres, while being present in a quantity above 10 c.c. Professor Starkey claimed to have had numerous experiences where, coli being detected only in large quantities, say, of 55 c.c. or of 100 c.c., the waters were found to be undoubtedly the direct bearers of disease. He considered that the B. coli communis was a member of a much larger group, the colon typhoid family, and that while some members of this group would produce typhoid, others being harmless, there existed a host of organisms in between likely to produce slight indisposition, sickness, severe sickness or typhoid fever. His words were: "It matters not in what quantity of water they are found, whether in one, three, five, or one hundred cubic centimetres; they are there, and the trouble will certainly ensue if such waters be consumed." On the other hand, Dr. C. J. Russell McLean, at the same meeting, was of opinion that the water supply standards were not satisfactory, especially in the case of water from shallow wells. Judging by his own district (Doncaster), he found that the shallow cottage wells yielded water quite impure according to modern standards, but that they did not produce typhoid as a rule, such cases being rare in the rural districts, while in cities and large towns where the public supplies were under control and scientific observation, typhoid fever either existed regularly or occurred periodically. The author would ask whether under these circumstances the scientific control was satisfactory.

Dr. Sims Woodhead, in evidence given before the Committee of the House of Lords upon the Cambridge Bill, went so far as to say that no water supply in the Kingdom coming from the chalk would satisfy the Board of Trade standard, viz., that the water should not contain more than 100 micro-organisms per cubic centimetre.

Dr. McWeeney, in a paper read at the Dublin meeting of the Sanitary Institute, in 1910, made use of the following words: "Coming now to the examination for intestinal organisms, I

will at once avow my whole-hearted adhesion to the coli test, and to it alone. I have never been able to satisfy myself that streptococci isolated from tubes of glucose broth, with or without neutral red, were really of fæcal origin. In the absence of a positive coli test I should attach no importance to them whatever; in its presence I should attach no importance to their absence." Also: "The only organism of intestinal origin which I now test for as part of the routine examination of potable water is B. coli."

Dr. Rideal's words with regard to the coli test are as follows: "There has been a tendency in recent years to make the coli test more and more severe as an index of purity or suitability of a water for drinking purposes. It is difficult to see what limit the modern bacteriologist should fix so as to be satisfied in this respect."

Dr. Houston has clearly stated that he is attempting to purify the London water to such a degree that coli may be absent from 100 c.c.

On the other hand, there are those who do not seem to regard the coli standard, taken by itself, as of much importance. Mr. Dibdin, in a lecture given at the Municipal, Building and Public Health Exhibition, in 1908, stated that: "There is no evidence that the B. coli communis is itself pathogenic, its absence does not convey any meaning other than an index of the possibility of more objectionable organisms gaining access to a water supply, the argument being that if an excessive number of B. coli are present in a given quantity of water there is no reason why, under certain circumstances, other sewage bacteria may not be present also." He also says that "to condemn a water which shows no sign of contamination other than a few B. coli communis and gives negative results to all tests for other objectionable bacteria, and also fails to respond to the most delicate chemical and microscopical tests for those substances which are known to be present in sewage-polluted waters, a water, in fact, which exhibits all the characteristics of an exceedingly pure water, except for the presence of the aforesaid few B. coli—to condemn such a water is rash in the extreme." Thus it appears that Mr. Dibdin does not, or did not when he gave his lecture, consider the presence of B. coli sufficient evidence upon which to condemn a sample of water, but he was surely allowing no factor of safety in saying this, or the probability is that one would have to go far before finding a water which would come up to Mr. Dibdin's description. Although Mr. Dibdin at that time did not consider the presence of coli as being necessarily dangerous, he undoubtedly accepted the water as safe bacteriologically when it had passed the coli standard, for he states that: "The absence of this organism, which is so widely distributed, denotes that there is no risk of serious contamination, and the failure to detect it after

stringent search warrants the water as wholesome from the bacteriological point of view." Thus, although the first statement conveys the impression that the presence of coli is not necessarily a serious matter, the second statement clearly shows that Mr. Dibdin regards the absence of coli as a positive proof of the bacterial purity of the water.

There is apparently a pious opinion on the part of certain persons that if the coli do not come from sewage the case against them altogether falls through. Why it should be assumed that water polluted, say, by stable drainage is fit to drink, has puzzled the author for some time. It is not at all uncommon to find the scientist making a distinction between water which may have been polluted by sewage, such as, say, the water from the Thames and Lea, and water which is gathered on the open moor, and which has, presumably, been polluted by animals, but which may, for all one can tell, have received human pollution. Of course, it is only guesswork in either case, yet we find that it is seriously suggested, and moreover, generally accepted, that a considerable difference should be made. For instance, Dr. McWeeney, in the paper already quoted, makes the following statement :—

"With regard to the number of typical coli that may be permitted in good, potable water, in Ireland at least, we may safely draw the line at 1 per c.c. in the case of upland surface (not storm) water and water from shallow wells, and at 1 in 10 c.c. in the case of deep wells. I am well aware that some (Savage, for example) have propounded standards that are more stringent. But my experience is that many excellent water supplies derived from upland surfaces, the principal animals on which are sheep, would have to be condemned if we were to insist on the absence of coli from 10 c.c. Even after storage in open reservoirs coli is often present in considerable numbers, owing, as I have reason to believe from personal observation, to the numerous sea-gulls that frequent such sheets of water. Even in samples from deep wells, where local inspection revealed no source of contamination, I have frequently found typical coli in 10 c.c. All things considered, it is better to take a lenient standard and to adhere to it strictly. The one above mentioned, 10 c.c. for surface, 100 c.c. for deep water as the minimum in which coli should be permissible, seems to me to comply best with the conditions prevailing in Ireland." The above is quoted from the Journal of the Royal Sanitary Institute. A misprint may have occurred, but as it reads we have a choice of at least two standards, and possibly of four.

The author does not wish to make any adverse comment upon this suggestion of Dr. McWeeney, but he does think that the standards appear to be inconsistent. Who can possibly tell what such pollution is due to ?

A better example of the pious opinion above referred to may be seen in a paper read by Mr. D. G. Revell, recently reported in the *Canadian Engineer.* After laying great stress upon the importance of the examination of the source of supply in judging the quality of the water, the author describes a case in which he was asked to examine the well water at a house in which there were then six cases of typhoid. The author states that : " For months previous to the onset of these cases the well water was also used by a lot of other persons, none of whom developed typhoid. *This was a biological test that exonerated the well quite clearly*, and much more certainly than all the chemical and bacteriological tests could have. Indeed, these would have condemned the well, for it was just beside the barnyard, and the stand, or well cover, had openings (for the rods of the double force pump) through which the manure, brought there by the farmers' boots, was being washed every time the water was pumped. It was winter, and one could see the manure right there, and see it washed into the well whenever water was pumped. Seeing is believing, and it required no analysis to prove that that well was both chemically contaminated and also contained plenty of colon bacilli from the barnyard manure. *Yet the well played no part in the typhoid outbreak*, for which it had been blamed. A brief study of the cases revealed a 'walking case' as the originator of the outbreak by contact." One would like to know the reasons why a well grossly contaminated in this manner should be considered to have played no part in the typhoid outbreak. It is pure assumption. If barnyard pollution or animal pollution is harmless, why is it that the Royal Commission on Sewage Disposal in their Fifth Report make the following statement ? " We are satisfied that rivers, generally those traversing agricultural as well as those draining manufacturing or urban areas, are necessarily exposed to other pollution besides sewage, and it appears to us, therefore, that any authority taking water from such rivers for the purpose of water supply must be held to be aware of the risks to which the water is exposed, and that it should be regarded as part of the duty of that authority systematically and thoroughly to purify the water before distributing it to their customers." If barnyard pollution is harmless, why should the drainings from manured fields be regarded by the Royal Commission as dangerous, so as to make it part of the duty of the water authority systematically to purify water so polluted ?

It is a generally accepted fact that a whole community may go on drinking polluted water for a long time without any noticeable harmful effect, and that suddenly an epidemic will result. There are innumerable instances to prove this point.

In the description of some typhoid epidemics in Indiana, Dr. J. H. Simonds, Superintendent of the State Laboratory of

Hygiene, mentioned a polluted spring supplying a school. The pollution was the result of an open-jointed pipe sewer laid in gravel parallel and near to a leaky tile water pipe carrying spring water. The contamination was so great that the typhoid bacillus was isolated from samples taken. When this spring water was shut off the epidemic ceased, yet *the same conditions had been in existence for nine years without ill-effect.*

This result is in agreement with what has occurred in a very large number of other places. When a violent epidemic of typhoid occurs in a town it is generally found to be due to the polluted springs or other sources which have been supplying the town apparently without causing trouble for many years. Statistics, however, show very clearly that when towns have been supplied with purer water, there is a corresponding fall in the typhoid rate. It is generally accepted that a person in good health may sometimes drink dangerously polluted water without harm, and that the system may even be trained to tolerate such pollution in the same way that one may gradually accustom oneself to taking large doses of a poisonous drug without suffering any immediate discomfort. Under these conditions the fact that a water can be consumed by a given person, or even by a given number of persons, without producing typhoid, cannot be taken as proof of the purity of the water. It is therefore surprising to find that Dr. Houston, in a recent report, actually suggested as a proof of purity the fact that he personally had consumed a certain quantity of water known to have been infected with typhoid germs originally.

The death rate from typhoid fever in the United States was recently stated in an article in the *Surveyor* to be 46 per 100,000 of the population, as against 11·2 in England and Wales, 7·6 in Germany, and 6·2 in Scotland.

As far as one can gather, the high typhoid rate in America is due to the fact that river and lake supplies are largely used, and that these are polluted with sewage. When one finds that Toronto has to sterilise water drawn from Lake Ontario, and that Montreal has to sterilise water drawn from the St. Lawrence River, as the consequence of typhoid epidemics, it is clear that the fact that sewage is discharged into a large river or large lake, where under given conditions it might, according to some authorities, get enormous dilution and purification by storage, does not save such supplies from typhoid. The larger supplies which are drawn from smaller rivers in this country must of necessity contain and do contain coli organisms in large numbers, and by inference, germs of more harmful nature.

Mr. John R. Downs, Physiologist to the United States Government, carried out certain experiments in connection with water purification at Panama. Certain watersheds were completely depopulated, the roads were diverted from them, and

pollution was prevented by police inspection, but notwithstanding these precautions it was found that coli were present in the waters. Sometimes they were to be found present in half a cubic centimetre. Mr. Downs, feeling sure that the coli were not due to human pollution, attributed the presence of coli in the soil to the presence of birds and small animals on the watersheds. In a series of experiments made with 44 samples of the earth taken from the watershed areas, coli were found in 20 milligrammes or less in over 62% of the samples. He therefore assumed that the presence of coli was no indication of danger, because he found, as others had before him, that, as is the case with typhoid germs, coli could live in the soil. The author is again of opinion that such a conclusion was illogical. In the face of the evidence given above as to the danger indicated by the presence of coli, it is begging the question to assume that any water is safe when coli are found in it in such large numbers. In one case we have Professor Starkey demonstrating that water which could not be found to contain coli in a sample of less than 100 c.c. actually produced disease, and in the other we have Mr. Downs ready to ignore their presence in half a cubic centimetre, merely because he has no reason to believe that the water is polluted. Surely, if such views are to be accepted as correct, not only does the coli standard become absolutely useless, but the work of the chemist and of the bacteriologist becomes useless also ; all that is required is a person possessing common sense to look around and see that the water is not grossly polluted.

Mr. Revell, in his paper, already quoted, practically sums up the case for the water examiner by saying that the data upon which he must work are : (1) the history of the use of the water, especially its effect upon health ; (2) the data gathered from the careful inspection of the surroundings of the source of supply ; (3) waters gathered from an unpolluted source in the same locality during the same season ; (4) the ordinary analysis of proper samples of the water ; but he states that "of these four requirements the first two are more necessary than the last two." Until some standard for all cases is fixed the position of the scientist at the present time practically amounts to this : Tell me the source from which the water comes, and show me whether it is polluted or not, and whether it has produced disease or not, and I will then adapt my standard to suit the requirements of the sample in question. If I do not see any obvious cause for pollution, I will allow you to have coli in half a cubic centimetre ; but if I think that there is any risk of pollution I will demand the absolute absence of coli from 100 c.c. or from 1,000 c.c. for that matter. The scientist is, no doubt, quite capable of saying whether the water is fit to drink or not, but he dare not adopt a fixed coli standard because he would have to condemn half the supplies in the country, or probably a larger proportion of them.

His argument is unassailable in one way, viz., that the proof of the pudding is in the eating ; such and such a water does not produce disease, therefore it is not polluted ; or if it is polluted the pollution is of no consequence. But we need no scientist to tell us this ; it ought to be possible, and no doubt is possible, to fix a standard conformation to which would be a *proof* of safety against certain defined water-borne diseases. It certainly in the present state of knowledge would be impossible to fix a standard which would prove conclusively that water was absolutely incapable of causing harm of any kind. This is shown in the quotations given above from Dr. Thresh, Dr. Sommerville and others, and if all the spore-forming bacteria were removed and the water were absolutely sterile, it has been urged that the water would still produce disease owing to the absence of certain beneficial organisms. Sir John Moore, at the Dublin meeting of the Sanitary Institute, said that many of the bacteria in water were possibly nutritive rather than harmful, and the author has had an instance reported to him of disease caused on board ship, due, in the opinion of the medical man on board, to the use of distilled water for drinking purposes.

The unpleasant possibilities demonstrated by the scientist with regard to the quality of the water are unpleasantly supplemented by the pessimistic statements which have been made for some time past by various authorities as to the pollution of waters generally. Mr. Baldwin Latham, at the Brighton meeting of the Sanitary Institute, read a paper on the " Influence of the Underground Waters on Health." After a lifetime of careful study he presents a mass of information which clearly points to the fact that certain diseases increase and decrease in direct relation to the rise and fall of the levels of the underground waters, and that percolation from the surface is the cause of pollution, but he offers no cure beyond stating that the lessons to be learnt from the observations of underground water and the outbreak of disease appear to be the necessity of keeping the ground free from pollution and of establishing works of water supply under such conditions that it is impossible that the water may receive any pollution. The Local Government Board Report upon the Cambridge Water Supply declared that the continued use of that part of the company's water which was derived from the lower chalk under the then existing conditions was dangerous. If that supply, which is really far removed from any obvious source of pollution, is not considered safe, it is a stretch of the imagination to consider that a great many of the chalk wells in worse positions are safer.

Mr. Baldwin Latham, in the paper above referred to, demonstrated that ninety-nine out of every hundred cases of enteric fever were due to the use of polluted water, and that " there is in the soil a natural habitat and breeding ground of typhoid fever

outside the human body," a most important point, which is, moreover, borne out by the fact quoted by Dr. Rideal in " Water and its Purification," viz., that Dr. J. Robertson, Medical Officer of Health, Sheffield, found that during warm weather typhoid bacilli, placed in soil, continued to multiply for at least 143 days. The cold weather, however, killed them, but it was found that they would live through the cold weather if various organic substances were added, and they actually did live in the soil through such conditions for 315 days. These experiments were confirmed by Dr. Sidney Martin, of the Local Government Board. It may be urged that the typhoid germ would also survive in water if the water contained substance for its nourishment, and who shall say that many raw waters do not ?

Other recent papers have pointed out the dangers which exist owing to the corrosion of well tubes and leaking well linings. Dr. J. W. Miller, at the Brighton meeting, drew attention to outbreaks of typhoid fever caused by river pollution. The causes of pollution are daily increasing, the ordinary sewage disposal works do not remove the harmful bacteria. In districts where the soil is porous or fissured there are always to be found soakage pits, cesspools, graveyards, leaking sewers and drains innumerable to cause pollution to the underground water. The Joint Committee of the Houses of Parliament in connection with the Water Supplies Protection Bill have pointed out that the powers for protecting rivers possessed by the local authorities are not effectively exercised by them, and they consider that a remedy for this state of things is urgently called for.

The remarkable effect produced by purifying polluted water is shown by a table published by the New York State Department of Health, which gave the mortality from typhoid fever for the past ten years in the cities of that state.

For instance, Albany had an average typhoid death rate of 88·8 per 100,000 before the introduction of sand filters, while after their introduction this death rate fell to 23·7. The Binghamtown typhoid death rate was reduced from 39·3 to 11·7 after the introduction of mechanical gravity filters. A reduction in the typhoid death rate varying from 24·4 per cent. to 78·3 per cent. is shown in the case of ten cities resulting from their improved water supplies.

A comparison is made between the typhoid death rate in each city in the year 1907, as compared with the average for the same group for the ten preceding years. The results are of great interest, as it may be seen that the cities which made no changes in their source of supply or method of purification during this period of ten years showed very little improvement, while those cities which made use of modern and improved methods reaped the reward of having their typhoid death rate considerably reduced.

Cities using unfiltered lake water showed an average typhoid death rate of 26·8 in 1907, as against a ten years' average of 27·6.

Cities using unfiltered river water showed an average death rate of 57·1 in 1907, as against a ten years' average of 57·7.

Cities using filtered water without making any improvement in method throughout the ten years showed an average death rate of 45·1 in 1907, as against a ten years' average of 45·8.

Cities having introduced filtered water since 1902 showed an average in 1907 of 37·8 as against 59·7 for the ten years, clearly showing the result of the improvement.

Cities changing to spring or well water since 1902 showed an average death rate in 1907 of 4·35, as against a ten years' average of 36·3.

The improvements effected in those cities have produced a decided change for the better, but they have not altogether got rid of the typhoid. Apparently the reduction of typhoid is in proportion to the amount of purification effected, and if a rigorous coli standard had been enforced, and if authorities had been compelled to purify their water up to that standard, it is only to be assumed that many more lives and much sickness and loss of money would have been saved. This conclusion has apparently been grasped by the many cities in America where absence of coli is now required and obtained. Their future health statistics will prove the merits of the author's assumption.

The argument is often brought forward that to purify polluted water is objectionable, and that water should always be obtained pure at the source. This is, however, often absolutely impossible. The difficulty of obtaining pure water is daily increasing, and for that reason it is necessary for the chemist and bacteriologist to increase his vigilance. The first line of defence is to exclude pollution, and the second is to have a standard for purification so high and so rigidly enforced that whatever pollution takes place the water may be purified. No sailing near the wind in this respect should be thought of.

As an instance of what ought *not* to be done, the author would quote a case which came before him the other day, in which a chemist, asked to report upon a sample of water for a client whom he wished to treat kindly, said, in his report, that the water was quite suitable for domestic purposes, *but should be boiled* : the water, it may be added, showed clear signs of sewage pollution.

Conclusion.

The author's object in producing the number of typical conflicting statements given above is to attempt to bring home to the chemist and bacteriologist the impossibility under present conditions of agreeing upon any standard, conformation with which shall prove that water is incapable of producing disease in

a greater or *less* degree. What they can do, and what they ought to do, is to fix a standard which shall prove that the water is free from given definite organisms believed to be harmful. Thus, if absence of coli were insisted upon, one might be reasonably sure that typhoid germs were absent, but according to the statements of thescientists quoted above, absence of coli does not necessarily prove the absence of certain other organisms, more or less indefinite at present, which they believe to be harmful in a minor degree. Until we can be assured more definitely as to the exact nature of these other dangerous organisms, and to the manner in which they may be got rid of, it is obviously impossible to take much account of them. The true scientist is, above all things, conscious of the smallness of his knowledge. There may be an infinite number of harmful things present in water, of which we know nothing at present. Science may in time discover them, or prove their absence, but it is impossible to take any serious account of them until they have been discovered. With regard to coli, typhoid, and other well defined water-borne disease germs, there is no such difficulty. If the scientist believes that they should be excluded, he should say so in no uncertain manner. If the scientist will fix his standard, we, as engineers, are prepared to make any water conform to that standard. It matters not to the engineer whether water comes from a deep well, from a shallow well, from a river or lake, or from the surface of moorland. He is quite prepared to purify that water, however much it may have been polluted, so as to bring it up to the highest standard required by the scientist, and the scientist has no excuse for shifting his ground and modifying his standards so far as the engineer is concerned. The modern methods of purification are numerous, and there are plenty of examples in this country and elsewhere where water originally polluted is being brought up to a very high standard of purity. Doubtful and impure supplies ought not to be tolerated, seeing that the machinery exists for purifying them.

Although it is possible to purify water to any required degree, this does not afford the slightest excuse for acquiescing in the pollution of water supplies. Here again it rests with the medical authorities, and with the chemist and bacteriologist, to insist strictly and uniformly upon the prevention of pollution. If they will do so, we, as engineers, are quite prepared to make all sewers, house connections and house drains as watertight as we make our water mains. We are prepared to do away with every soakage pit or cesspit in the country ; we are prepared to purify all sewage discharged at outfall works up to any degree of chemical or bacterial purity required. Yet the River Thames, from which the supply of London is drawn, receives the sewage of 800,000 persons, together with other impurities, which reach the river without any attempt at bacteriological purification. At the

present time an enormous amount of work is done in discovering the causes of pollution and in the work of purification both of water and of sewage, but no one has had the courage to tackle the matter in a whole-hearted manner. We all acquiesce in the pollution of our sources of supply, and we all acquiesce in cutting down the cost of purification and protection works to a minimum. Some day it will be recognised that this is false economy, in the same way that it has been recognised that it is cheaper in the end to construct our roads, railways, bridges, machines, engines or buildings of the best material and in the best manner possible.

The President said that, in rising to propose a vote of thanks to the author, he undertook the duty with much pleasure, because, not only had Mr. Shenton dealt with the subject in a capable and interesting manner, but the fact that he had contributed the paper in addition to fulfilling his rather arduous duties as Vice-President of the Society demanded special recognition.

The author had clearly stated the object which he had in view in the conclusion of his paper, and in the previous part of the paper he had stated the position of the scientists in the matter, using rather important words : "Tell me the source from which the water comes, and show me whether it is polluted or not, and whether it has produced disease or not, and I will then adapt my standard to suit the requirements of the sample in question." He (the President) thought that the paper ought also to be looked at from the engineering side. Engineers would be only too glad if the scientists would take steps to force the issue, but he also hoped that the engineers present would defend their position. In discussing the paper in the abstract it appeared necessary to distinguish carefully between what was scientifically right and what was financially desirable. One could well imagine that the engineer who was general administrator to a large water company was inclined to look with prejudice upon a standard which would put his company to large expense for extra works of purification, and the more so as, in all probability, the water supplied from the works apparently produced no ill-effects, although it did not comply with such a coli standard as that recommended by some of the greatest authorities. The object of the meeting should be to consider the matter impartially, without reference to special cases. The fact that it would be very inconvenient to adopt a higher standard than had, up to the present, been generally enforced, should not affect the decision of scientists when they had to state whether a water was safe or unsafe for human consumption. In applying higher standards, it would probably, for many years to come, be necessary for

certain authorities to accept a risk, but they should do so with their eyes open.

The author's object was evidently to point out the advantages of agreement between the chemist and the engineer. The engineer ought to be able to tell what standard of purity would be required from him instead of the matter being left open to the judgment of individuals whose opinions might differ to such a degree that the engineer, in designing or carrying out his work, could never quite tell to what degree he ought to provide for his water purification.

The vote of thanks was carried with acclamation.

The Secretary then read the following communications:—

Mr. W. Pollard Digby.—Mr. Shenton's paper recalls to me my experiences in 1897 and 1898, when I was engaged on sewage sterilization work at a town in the Thames valley. I was the engineer in charge of the works ; the chemical and bacteriological advisers of my principals being the late Professor Kanthack and my friends Dr. Rideal and Professor Robinson. Sewage sterilization was then effected day in, day out, on a practical scale, but the effluent which I was given to treat was one which was of a distinctly poor quality chemically. Despite the warm advocacy of Professor Kanthack and Dr. Rideal, the authorities concerned insisted on judging the effluent solely on its chemical character, and paid no attention whatever to its bacteriological qualities. As a result of their regarding the sterile effluent as a species of painted lily, or as akin to refining refined gold, sewage sterilization was in that case abandoned, after nearly two years successful treatment. During that time the effluent in question was bacteriologically superior to the tap water at London or Cambridge.

If we have standards for milk and butter, and if we have a Food and Drugs Act which permits the seizure of food unfit for human consumption, it would be to the advantage of the whole of the community if standards of purity for water and for the sewage effluent which must enter so many watersheds whence drinking water is taken, were definitely laid down. When once we know what is required, sewage works and water works can be designed and administered upon the same practical and commercial lines as those of modern steelworks turning out standard sections, with materials of a definite chemical composition, and with definite mechanical properties.

I would suggest that the Council of the Society of Engineers should approach the Royal Sanitary Institute, and urge upon them the advisability of appointing a committee of chemists and bacteriologists who should lay down standards for drinking water, and for sewage effluents discharged into watersheds whence

drinking water is taken, in the same manner that the Engineering Standards Committee has dealt with Portland cement.

Mr. John Don.—We have here a valuable contribution to the literature of water purification, because it collects the views of many authorities on the subject of standards of purity, with special reference to the bacillus coli test. It is true that doctors differ widely in regard to this matter, as differ they always will until the point at issue has been settled at the tribunal of scientific inquiry and research. As concerns the B. coli test, we must consider the circumstances under which it is brought into operation. There are two distinct cases. While authorities may fail to agree on the value or even the applicability of the B. coli test in the one case, they may not logically do so in the other.

Let it be remembered that the B. coli test, as now insisted upon at many important installations, refers to water that has been purified by *artificial* means. Of its value in this domain, there is no room for difference of opinion. It has been abundantly shown that if a purifying plant can eliminate B. coli, it surely excludes B. typhosus and other pathogenic germs. To date, there is no evidence that a purifying apparatus which satisfies the B. coli test has been the cause of epidemic disease of any kind. Vice-versa, it has been proved to the hilt that communities using water which satisfies the B. coli test enjoy almost total immunity fron enteric fever, beyond, of course, the occasional occurrences that may be due to " carriers " and accidental contagion that has nothing to do with the water supply.

Mr. Shenton himself brings forward statistics to show the immense superiority exhibited by the health records of towns nourished by artificially purified water over those of communities who are still content to potter along with polluted and untreated supplies.

In the other case, the one in which authorities on water purification may legitimately hold different opinions, a little consideration will show that the B. coli test, as usually understood, may not be at all times a reliable standard of purity. Waters that are regarded as " naturally pure " to such a degree that the analyst, after examining a number of samples, reports them to be potable and fit for domestic use—may quite well suffer from *occasional* pollution. More especially is this so with surface waters, and deep wells too may receive unexpected additions of objectionable matter, just as was the case at the Cambridge County Asylum. The fact is, that the purification results secured by natural means are uniform, so long as the antecedents are uniform. So long as the " history " of the water supply remains just the same as it was when the samples

sent for analysis were drawn, so long will the quality of the water remain the same and no longer. Therefore, the analyst may report " pure " after satisfying himself regarding ten or a hundred samples, and yet it may happen that an unusual rainfall after drought will convey to the channels of supply matters which were never there when the samples were taken. Cesspools may leak, drains may become imperfect, carriers of enteric may be imprudent, and if any of these accidents occur, somebody's water may be polluted. Such occurrences are rare, it is true, and should they occur they are seldom followed by sinister consequences owing to the warfare waged by natural agencies against water-borne pathogenic germs.

It remains to be said that should a natural water which is almost always pure, be tainted with disease-producing microbes, the B. coli test would hardly fail to respond. Sewage, and all water-carried contaminations of the same derivation, contain B. coli in abundance. If waters so tainted convey B. typhosus, they will also convey B. coli. This inference from Dr. Houston's researches has been invested by his labours with so high a degree of probability that in the absence of any well devised and extensive array of evidence to the contrary, we must regard it as proven. Hence we conclude that the B. coli test applied "on the spot," that is at the exact time that the water was conveying pathogenic germs, would certainly have done all that was expected of it.

Finally, the value of the B. coli test as applied to the effluent of a purifying plant rests upon the uniformity of the system of working the apparatus, as well as on the precautions taken when there happens to be any marked deterioration in the quality of the raw water. The analysis of a tiny sample, say one-tenth of a gallon, is then a scientific guarantee that thousands, and it may be millions, of gallons passing on to consumers between the periods of testing, are of as good quality as the sample analysed.

In the case of unfiltered waters, if contamination occur, there is often no warning, no danger signal, and the bacteriological analyses are often made at wider intervals, because the water is held to be above suspicion. And so it does chance that isolated cases of infection by waters, naturally pure, do occur, but that in no way invalidates the supreme importance of the B. coli standard.

Prof. E. J. McWeeney.—I must confess to disappointment on reading Mr. Shenton's paper. I had expected to learn something as to the methods now employed for purifying water " no matter how much it may have been polluted, so as to bring it up to the highest standard required by the scientist " ; instead, I find a number of more or less conflicting statements made at one

time or another by a number of more or less competent persons, with regard to a subject of admittedly considerable difficulty, viz. :—the fixing of bacteriological standards of water-analysis.

From time to time in the development of our knowledge, periods occur during which it is unsafe to be dogmatic or to lay down precise lines of classification. To do so would be like endeavouring to draw a detailed map of an unexplored country. We must wait till we have accumulated more facts. Now we are in such a period with regard to standards in water-analysis. The genuinely scientific analyst will, under existing conditions, strive to steer his course between the Scylla of unsafe leniency, and the Charybdis of impossible and unnecessary stringency. In his endeavour, he will not content himself with looking at the subject from his own narrow standpoint. He will try to get as much information as he can about his sample, and be guided in his decision by the consideration of the totality of its characters.

The data sought for by my friend Dr. Revell, Government analyst to the State of Alberta, seem to me to be just the very oints which the scientific analyst requires to know before he commits himself to an opinion as to the probable effects of a source of water supply on the health of a community. The author's mental attitude seems just the reverse. He is inclined to sneer at the endeavour of the analyst to take into account these all-important matters. He would have the chemist confine himself to his test-tube, and the bacteriologist to his culture-plate, and fix a rigid standard "conformity to which would be a proof of safety against certain defined water-borne diseases." Doubtless it would be possible to frame such a standard. But what, may I ask, would be the use ? Very few, if any, of our existing supplies would constantly conform to it. Moreover, the universal experience as to the harmlessness of supplies falling far short of it would soon bring its exaggerated requirements into disrepute.

The author appears inclined to scoff at what he terms a "pious opinion" on the part of "certain persons," of whom I am one, that "if the coli do not come from the sewage, the case against them falls through." He appears to object to the setting up of a distinction between water polluted with human sewage such as that of the Thames or Lea, and that which is gathered on the open moor, and has presumably been polluted by animals. I take the liberty of assuring him that the distinction is by no means a "pious opinion," but one of the most vital importance. It is based upon the fact that human sewage—I observe, by the way, that the word *human* is omitted in the passages just quoted—is liable to contain the typhoid bacillus, whereas, so far as we are aware, animal or stable sewage is not liable to do so. The presence of coli in certain quantity indicates to the bacteriologist the pre-

sence of matters of excretal origin, in a word, of sewage. The coli of itself is no harm. Coli is not a disease-producing organism in the same sense as are typhoid and cholera bacilli. We take it into an alimentary canal already swarming with it. Coli is not a danger, but a danger-signal.

Everything turns on the recognition of the source of the coli, whether derived from human or from animal excreta, and this, unfortunately, is just what we are unable to do by bacteriological methods. Hence the need for local inspection. The author dismisses the distinction as mere guesswork. So it would be, were the bacteriologist to attempt to found upon the presence of coli inferences not logically deducible therefrom. And that is just what the bacteriologist very wisely refrains from doing. He not only "seriously suggests," but he actually insists, upon the strict maintenance of the distinction between waters contaminated with human and with animal excrement. So long as he keeps on being unable to tell whether a given strain of coli is of human or of animal origin, so long will he insist upon his results being interpreted in the light of local inspection.

Further on, in dealing with the experiments of Mr. Downs, the author falls into the same error. Mr. Downs, finding coli in the water of a depopulated and unpolluted water-shed, very properly concludes that the presence of coli is no proof of danger. The author thinks this conclusion illogical. May I ask on what grounds? What are the dangers to health which he considers to lie in the use of such waters.

Elsewhere he refers to the experiences of Prof. Starkey. With regard to these I can only say that until we are more accurately informed as the nature of the diseases alleged in the passage quoted on p. 163 to have been conveyed by water containing coli only in 55 or 100 c.c. we shall do well to avoid placing reliance on statements that conflict so strongly with ordinary experience.

The author then goes on to say that if such views as those of Dr. Downs are to be accepted, not only does the coli standard become useless, but the work of the chemist becomes useless also; all that is required is a person possessing common sense to look around and see that the water is not grossly polluted. With this view I cannot agree. The work of the chemist and bacteriologist reveals in water the presence of matter dead and living, which, when present in certain kinds or in certain quantities, points to the possibility of danger. Their work requires to be supplemented by that of the local inspector, but cannot be replaced by it. The chemist and bacteriologist can tell us to what extent the water is being polluted. The local inspector can appraise the likelihood of such pollution being actually or potentially dangerous to the public health.

Finally as regards my own observations as quoted on p. 160. I can only say that I adhere to them whilst wishing that I had expressed them more clearly. I do propose two standards, the more lenient for upland surface waters and shallow wells, as being more liable to contamination with animal excreta, the more severe for deep wells, as being less liable. In the former case, the presence of coli in 1 c.c. condemns ; in the latter, its presence in 10 c.c. In neither case is the condemnation absolute. The word merely means that the water cannot be passed as satisfactory in the absence of explanation of the presence of coli—an explanation based on the results of skilled local inspection. Nor does the word condemn here mean "regard as dangerous." In view of the proved harmlessness of coli, such a position would be unjustifiable. It merely means that in the sample under examination there are present more coli germs than are usually found in pure waters of that class, a circumstance which would excite suspicion and give occasion for minute and skilled local inspection, in order to ascertain the probable source of contamination. Should the result of such inspection prove negative as regards pollution from human sources, I should have no hesitation in permitting the use of the water.

There are many other points in this paper with which I would gladly deal. But I feel sure that other speakers will refer to them, and will conclude by saying that if I have adopted a controversial tone, I trust I may be excused in view of the grave importance of this subject to the public health.

Dr. J. W. Miller, M.D.—Whatever the source of a water supply, it is most important that it should be protected from any pollution of human origin. The presence of B. coli in 10 c.c. of a moorland or well water, in which there was very little likelihood of pollution from human excreta, would be considered of less significance than the presence of the same organism in 100 c.c. of a river water, where it was known that such water received the sewage from towns or villages on the banks. At the same time, water which does not contain B. coli in 100 c.c. would usually be considered fit for drinking purposes. So long as there is no test for distinguishing between B. coli of animal or human origin it is usually necessary to eliminate these organisms from a water to render it safe for drinking purposes.

There are towns in England, which still derive their water supply from a river source, and I think that most people will agree that crude sewage from towns and villages on the banks should not be allowed to pass into the stream.

Pollution of rivers and streams can be prevented under the Rivers Pollution Prevention Acts of 1876 and 1896. The Royal Commission on Sewage Disposal in their fifth report referred to a

chemical standard for sewage effluents, but no bacteriological standard has been stated. In regard to such a standard Sir Rubert Boyce, one of the Commissioners, gives his opinion in the second report, in connection with the River Severn investigation.

"Whilst it would be onerous to expect absolute sterility in any effluent running into such a stream, unless some simple method of sterilisation was discovered, yet a certain degree of bacterial purity, as shown by the B. coli test, might be insisted upon in addition to the chemical tests, for it would indicate the extent to which intestinal bacteria were reduced by the method of sewage treatment employed."

By means of contact beds or percolating filters, after preliminary treatment, a clear non-putrescible effluent can be obtained, but even under the best conditions the reduction in the number of B. coli present would not be more than 70% to 80%. With the best land treatment a reduction of 90% can sometimes be obtained. After treatment of sewage by any of the above methods there would still remain from 1,000 to over 10,000 organisms of the B. coli group per c.c.

In the fifth report of the Royal Commission on Sewage Disposal an account is given of experiments carried out by Drs. Houston and McGowan on the sterilisation of sewage effluents.

Using "chloros" (crude sodium hypochlorite) containing 10% available chlorine, they found that with a non-putrescible sewage effluent, assuming 10 hours contact, the amount required for the destruction of B. coli in 1 c.c. of the effluent varied from 1 to 25,000 to 1 to 50,000 parts, and they concluded that the cost would be from £1 to £2 per million gallons, and that under specially favourable conditions the cost would not exceed £1; with shorter duration of contact the cost would be greater. They state that the sterilisation (as regards B. coli) of a well clarified, well oxidized and otherwise well purified sewage effluent is thus not an impracticable measure, assuming tank accommodation for at least one hour, but preferably ten hours.

Experiments have been made in this country and America on the treatment of sewage effluents by oxychlorine and chloride of lime. The Baltimore Sewerage Commission, which has been carrying out an investigation since 1907, has found that three parts per million available chlorine will effect sterilisation.

As a result of experiments carried out by Boyce and his colleagues from 1899 to 1901, it was found that the effect of the flow of the sewage from the town of Shrewsbury into the river was felt at least 16 miles lower down in spite of the purification which was going on in the river.

In the case of a town deriving its water supply from a river, there can be no doubt that the best protection is storage of the water for a period of a month or longer as recommended by

Houston ; at the end of this the bulk of the harmful organisms present will have disappeared. But in some cases, on account of the cost, the provision of a large storage reservoir may be prohibitive. The question of obtaining the supply from another source might also in some instances be out of the question on account of the cost ; it is then important that the river supply should be kept as free from pollution as possible.

I quite agree with Mr. Shenton that at present confusion arises in regard to what should be considered a suitable bacteriological standard for a water suitable for drinking purposes ; in order to fix a standard or standards for various water supplies further information is required regarding the source of supply. The experience gained by such officers in connection with the various water supplies throughout the country, would enable them to decide what bacteriological and chemical standards should be adopted in different cases in regard to water and sewage effluents. The information which is at present being obtained through the Local Government Board in regard to the various water supplies should provide a basis for some action by the Government in regard to the protection of water supplies.

Dr. Samuel Rideal, D.Sc.—Mr. Shenton's luminous exposition of the difficulties of the subject is especially valuable at the present time, when after a period of calm we are awaking to the possibilities of great epidemics again invading us. It is a truism that the price of peace is incessant vigilance, and should this not be devoted to making our drinking waters always healthy—not "comparatively wholesome"—and systematically barring *all diseases* from entering our systems by this conduit ? At present we too often think only of typhoid, but it is now amply proved that bad water gravely affects the general health of the community. Hazen first noticed that where one death from typhoid has been avoided by the use of better water, a certain number of deaths, probably two or three, from other causes have been avoided, and what is called the Mills-Reinke phenomenon is that when purer water is supplied the general death-rate declines more rapidly than the typhoid death rate. Sedgwick and McNutt, after an examination of the subject in great detail in the last volume of the Massachusetts Institute of Technology Reports, have fully established the fact. But it is not only the death-rate, but the general health, particularly of the younger members of the community, that is improved by supplying a pure drinking water.

Mr. Shenton points out that engineers are quite capable of meeting the severest demands of scientists—these should be directed to the *destruction* of pathogenic organisms, rather than to their partial and somewhat uncertain removal as at

present attempted by very extensive and expensive plant. A simplification of this plant, applying afterwards either ozone or chlorine to get rid of the germs of disease, is the way that I think engineers should take for ensuring us continually wholesome water, almost independent of source, and though economy is not everything, I believe it could be done economically. Fuertes and others have shown us the enormous cost of disease to the community, and Dr. Eustace (Journal Sanitary Institute, Nov., 1910) has demonstrated the effect of hygiene upon wage-earning capacity—that money spent on public health is sound capital outlay—and hardly a point is more important than that our health should not be deteriorated or imperilled by impure water.

Mr. W. D. Scott-Moncrieff.—It appears as though we were now going through many changes with regard to several important branches of sanitation and its sister science of preventive medicine. The theories about air-borne diseases are being modified, and while "changes of air" as prescribed by the physician, are known to have marvellous effects, dependent on the most subtle variations of climate, it is now held from actual experiment that the interior of a large sewer is not deleterious to health.

As I said in a paper before the Royal Sanitary Institute, some time ago, there is no doubt our sanitary authorities, from the Local Government Board downwards, regarded the pollution of rivers as a danger to the public health, whether they were used as drinking supplies or not. Now it is alleged that culture plates can be exposed to the spray of septic sewage without shewing any signs of pathogenic growth. It follows from this that the same sewage, in a less septic form, flowing between the banks of a river must be altogether innocuous. What the public will come to think of these anomalies, while they remain unexplained, it is hard to say.

Mr. C. G. Stewart.—I rather demur to Mr. Shenton's observation on page 166 as to "typical conflicting statements." They seem to me to be only apparently conflicting, and to agree on most essential points as regards the ordinary methods of water supply.

With reference to the remarks on pp. 157, 161 and 162 that persons may become acclimatized to sewage, such immunity is only because the human organism includes (1) resistance to penetration, (2) actual digestion of organisms if they penetrate the digestive system, (3) destruction of them by phagocytes if they penetrate the blood. The defensive powers, however, experience an unfair strain if we are always calling them into action. Ill-health becomes constant, and disease ensues. The moral points to sterilization of pathogenic organisms, not simply limiting their

numbers. Most significant is the remark on page 165 as to local authorities not exercising their powers. I demur to the assertion on page 167 that it is impossible to take any serious account of harmful things present in water *until they have been discovered.* Are we to wait till an epidemic discovers them ?

Dr. J. C. Thresh, M.D., D.Sc.—The whole thing is too complicated to be very usefully dealt with at such a meeting. Every source of supply must be considered on its merits, and when all the facts relating to it are known, a provisional standard can be fixed. It is useless asking chemists and bacteriologists for standards. My experience is that the less practical experience such men have had and the more ready they are to fix a standard for everything.

The President then called on Mr. Baldwin Latham to open the discussion.

Mr. Baldwin Latham said that he did not think that bacteriology had succeeded, up to the present, to such an extent as to be able to discriminate with absolute certainty what waters were wholesome and what were not. It was very well known from what had taken place in connection with the great epidemics of typhoid in this country that the water producing the epidemic, in every instance, had passed the chemist as being water of the purest class and as not containing more than 0.04 of albumenoid ammonia per million parts. On the other hand, there had been epidemics, such as the epidemic that occurred a few years ago at Worthing, which was one of the most severe ever experienced in this country, in which both the chemical test and the bacteriological test were at fault, and the people were led to believe that the water was pure and began again to take it without observing the precaution of boiling it, and the consequence was that the epidemic increased to a very great extent.

With reference to the question of sewage getting into drinking water, he, when he was a young man, was a surveyor in a district in which a stoppage occurred in the sewers and at the same time a connection was discovered between the overflow from the pure water tank at the water works and the sewer. The sewage flowed back into the pure water tank at the waterworks and was distributed in the water supply of the district. The result of that was that there was not a single case of typhoid in the town, but that there were some thousands of cases of diarrhoea, of a very virulent character. That was the result of charging water, after filtration, with town sewage.

With regard to some of the diseases which were influenced by water, he thought that the temperature of the water had a great deal to do with the matter. For instance, summer diarrhœa

was not prevalent in country districts which, in many cases, drew their water supplies from shallow wells. Why was this ? The temperature of those wells never rose to a dangerous point, and, owing to their very low temperature, they were extremely agreeable for drinking purposes, and people preferred them to the water taken from water mains, the ordinary distributors in a town. Many people still imagined that the temperature of the water was the temperature at the source. For instance, they talked about water from the chalk being of such a uniform temperature all the year round, and so agreeable on that account. But the temperature of the water as delivered to the consumer was a totally different thing from the temperature of the water at its source. The water, after passing through a mile of mains, acquired the temperature of the ground at the depth at which the mains were laid. For between thirty and forty years he had taken the temperature of the water delivered direct from the mains at Croydon into his own house, and he found that the temperature varied from a little over freezing, in very severe weather, to a temperature of from 60 to 70 degrees in the heat of a hot summer. When the temperature of the water rose to over 60 degrees, and was maintained at that temperature for some time, summer diarrhœa became prevalent in towns.

Again, some people looked upon the absence of friendly organisms as a thing which ought not to occur, and thought that if the bacilli coli were killed other organisms which might have a beneficial result were killed. Take, for instance, the organisms which operated upon the organic matter so that a large amount of nitrates was obtained in the water. The question was whether water containing a large amount of nitrates was not a fruitful source of disease. It had been shewn that nitrates in water had increased disease, and there could be no doubt that the presence of those nitrates arose from the impurities which had been oxidised by those useful little microbes of which so much had been heard. These were matters which needed to be thoroughly discussed.

He did not believe in what the Americans called purification by dilution. In America a law had been laid down that, if a certain degree of dilution had been obtained, the water would be wholesome, and, although sewage and other impurities had been shown to pass into the water supply, if the stream was sufficiently copious so as to dilute it to a certain extent, the water might be looked upon as wholesome. He did not believe that, in the slightest degree. It always used to be said, when he was a young man, that a shrimp was a shrimp whether he was in a pint of water or a gallon of water. It was only a question of who was ultimately to get the microbes. If they were in a state of dilution of course the chances were not so great that everybody

would get them ; but, if there was a concentration of impurities, then there was a very great chance of the impurities exercising a deleterious influence.

There was no doubt that the most fruitful source of the bacillus coli was the friendly cow. The number of bacilli coli produced by a cow exceeded the number produced by any other animal. It had never been shewn that there was any product of the cow which was deleterious unless it was the cow-pox or something of that kind, which was of use as an aid in the prevention of disease.

It was very doubtful whether the coli test was of any value, especially when one could not discriminate between whether the coli had come from animals such as the cow, or from a human individual. There was one thing that should be done, and that was take precautions against any evil arising from impurities in water supply. Not a drop of water had ever been used in his house for the last forty years but what had been boiled first and had been allowed to cool in the open air and subsequently filtered. He traced to the adoption of these precautions the wonderful way in which his children had escaped all the ordinary types of disease to which young individuals were commonly subject. In old Roman times, water was regarded as a raw material which required to be decocted, or cooked, before it could be used. It was said that the Emperor Nero had his water boiled and then cooled in vessels placed in snow. So, although the system which he (the speaker) had adopted was one of the best modern modes for the prevention of disease, it was not a new invention, by any means. He was very much indebted to the author for the very great care which he had taken in the preparation of the paper and for bringing it before the Society in such a well defined form.

Lt.-Colonel C. H. Melville said that the author had very well placed before the Society a very controversial subject. His (the speaker's) experience with regard to water supply was almost entirely confined to India, where he had served for twenty years. His experience in India had led him to doubt absolutely the statement that the presence of enteric fever was an indication of the state of the water. His experience was that typhoid fever was not necessarily a water-borne disease at all. Cholera was. In the 'sixties cholera was severe every year, and the authorities paid attention to water. In the 'seventies cholera was present every year, and severe occasionally, and the authorities paid more attention to water. In the 'eighties a great deal of attention was paid to water, and cholera was rare. In the 'nineties cholera almost disappeared, and it was now, as regards European troops, practically absent. As pure water was in-

troduced, cholera disappeared. In spite of pure water being introduced, enteric increased. In Quetta, where the water supply was absolutely beyond suspicion, there was in 1898 quite the worst epidemic of enteric fever that he had ever seen, 232 cases out of three regiments in three months, and 75 deaths. That was absolutely and entirely unconnected with the water supply. On the other hand, he would mention his experience at Mandalay. The water supply of Mandalay was from the ditch. The ditch was about four miles long, and two hundred yards broad. It was kept full by a canal. It was used by the natives of Mandalay for drowning themselves and also cats and dogs, as well as for other purposes. That water was drunk by the garrison of Mandalay up to certainly 1905, and there had been no outbreak of enteric or cholera or dysentery. He had been asked to explain this, and he had not been able to do so. If the presence or absence of disease was going to be taken as a test of the purity, or otherwise, of water, there was an enormous *non sequitur* somewhere. People said, "There is this disease, and therefore the water is bad; there is not this disease, and therefore the water is all right." The two things did not go together at all. He had absolutely lost faith in the theory of taking disease as a proof of the purity or otherwise of water.

With regard to the question of standards, in England the authorities had not to deal with cholera. Cholera was fairly easy to isolate from water. If there was a cholera epidemic on, any ordinary bacteriologist could test for and isolate the bacillus, but he was almost certain that no bacteriologist had ever isolated and identified the bacillus typhosus in a water supply in the case of a typhoid epidemic. He was quite aware that ten years ago it was often said to have been done, but the examinations of that time would not be accepted now as being at all sufficient. Therefore, in this country as regards the bacteriological test the presence of bacillus coli, and as regards the chemical the presence of ammonia nitrates, and so on, must be relied upon. That was to say, the danger could not be found, but the danger signal had to be. This point had been brought out extremely well. Of course danger signals might be of varying degrees of importance. All that could be said was that if disease was present the bacillus coli would be present; it was impossible to say that because the bacillus coli was present disease was also present. It could not be said, "This is a danger signal of an absolute verity." It was only a roundabout danger signal. If the disease was there, there should be the signal; if the signal was present it was no proof that the disease was present. The same thing applied in the case of the chemical tests. They proved nothing, but they simply gave a hint. In the long run, it all came back to common sense; the use of the ordinary eyes and nose and

common sense, and not microscopes and test tubes, or anything of that kind.

He would like to mention two cases which he had experienced in India. On one occasion he examined a water chemically and bacteriologically. The bacteria were about 1 or 2 per c.c. There were no coli. He condemned that water. Some years later he examined another water which was swarming with bacillus coli and which was full of oxidisable matter, enough to build a house with. He accepted that water.

The first water came from the hills and within 50 yards of the water supply was a graveyard. The soil was impermeable but liable to fissures. Just as it happened no fissure had opened into the water supply shortly before. The graveyard had not been used much, though at the time he actually inspected the site, a burial was going on.

In the other case, the water he approved of came from a hillside where cattle were grazing, and the bacillus coli, which was there, came from cow dung. All one had to do was to put a fence round the space to keep the cattle off. If he had run a wire fence round, and then found bacillus coli, he would have known that the bacillus came from some man who had got through the fence.

The standards which he had referred to were not at the outset of the slightest use to him, personally, as a sanitary officer. Having got his local supply, and safeguarded it, and put up purification plant, and so on, he could examine the water chemically and bacteriologically and see whether his precautions were still efficacious. If he found bacillus coli and oxidisable matter, and so on, then he knew that something had broken down somewhere. But in the first case, he would not give anything at all for a bacteriological examination, or a chemical examination, without a common-sense examination of the site by the man on the spot. He knew that what he was saying was heresy in the opinion of the bacteriologists and the chemists ; but it was the opinion which he had come to after a good many years' experience of the subject.

It was impossible to fix a standard which would be applicable to all cases. In England it might be possible to have a standard which would hold good in Sheffield or Birmingham or Winchester; but no standard fixed in England was of the slightest use outside England. No standard in the North of India was any good in South India. Each place must have its own particular standard, the result of long experience of that place and of the particular water supply.

With regard to the remarks of the last speaker about summer diarrhœa, he thought that the speaker rather over-estimated the importance of the temperature of the water on that point.

His own experience was that it was due not to the water supply but to flies, just as he believed that enteric fever was due to flies. The temperature of 60 degrees F. was not a very favourable temperature for the development of the ordinary disease-producing bacilli, but it was a very favourable temperature for the propagation of flies.

In one of the communications which had been read, something was said about a bacteriological test of sewage effluent. He thought that to attempt to lay down any bacteriological test for sewage effluents was to mistake entirely what a bacteriological test meant. As to water, a bacteriological test was laid down, and it was said that the water was not to contain more than so many bacilli of a certain kind, for instance bacillus coli. The bacillus coli was not a natural inhabitant of water, and therefore it was quite right for a man to say "I will not have bacillus coli in my water," but the bacillus coli was a natural inhabitant of sewage, and no method of purification would reduce the number of bacillus coli, as far as he knew. The bacillus coli could live anywhere. If they were going to lay down tests for sewage of the kind suggested, they might as well boil their sewage straight away. If the sewage was sterilized, it would still have to be oxidised, and it would still have to go through purification tanks. Water and sewage could not be put upon the same footing at all.

Dr. David Sommerville said that the author had certainly brought together a number of conflicting opinions which he was afraid he could not reconcile. It struck him that Mr. Shenton as an engineer was asking too much of the bio-chemist when he demanded standards. Engineering, largely built on mathematics, was an exact or fairly exact science. Engineers had for thousands of years been collecting their inductions and were able now to make deductions fairly correctly. Bio-chemists were at present in the throes of collecting their inductions and might be able in the course of a few thousand years to draw deductions almost as nicely as engineers. He thought that all that the specialist was required to do was to put before his clients the present state of knowledge and leave them to use their own common sense in the matter. He agreed with Professor McWeeney's remarks.

It was now a matter of human experience that typhoid fever was carried by water; the recent case of Lincoln, in which fresh sewage was admitted to the water supply, admits of no other explanation. That there are other modes of conveying typhoid, such as the human subject, dust, and flies, does not in any way invalidate the proposition that water is a medium of typhoid infection. If it be agreed that the sewage of our towns contains large quantities of human fæces, in much of which B. typhosus exists, bio-chemists are right in asking the public to safeguard potable waters to the utmost against sewage.

His (the speaker's) paper referred to did not suggest that other bacteria should take the place of B. coli ; where these other bacteria existed B. coli also existed and remained an indicator of materials of intestinal origin.

The present state of knowledge did not admit of hard and fast standards. But in order that all possibility of danger of bacterial infection might be removed from potable water supplies he had advocated the exclusion from all such supplies of both domestic sewage and domestic sewage effluents. He still adhered to this position.

Dr. Herbert Lapworth was afraid that he could not join in the general admiration for the particular quality of common sense. He thought that the value of what was commonly understood as common sense was a good deal exaggerated, because common sense was really opposed, very often, to the use of available knowledge. Until the time of Bacon, people had been living on common sense with little progress, and it was not until the Baconian philosophy was evolved that the scientific methods of the present day originated, with the resulting rapid strides of progress. There were many examples where common sense alone could be shown to be entirely misleading ; common sense with knowledge was what was required.

Of course, waterworks engineers knew that in this country there existed numerous cases of pollution of water supplies, particularly in farming and country districts. He was familiar with a case where a boring was sunk just outside the fence of a graveyard. The water was sent to be analysed, and the analyst wrote, after his analysis, that the well must be in proximity to some ancient burial ground. This was rather a striking instance of what the science of the analyst could do sometimes. The analyst had absolutely no information as to the site of the particular boring. The borings were proceeded with, and the water was pumped, and after about three weeks or a month samples were again sent to the analyst, and he said that it was all right and the work went on. But as the pumping decreased the water got back into its old state again, and was condemned. This showed how accurate, sometimes, the analyst could be.

There was another matter where he thought common sense alone was misleading with regard to the sources of pollution, which formed one of the most important points in connection with water analysis, and that was in the examination of sites. Many books on public health and elementary books on water supply said that there should be no source of pollution on the area covered by the circle of influence produced by the pumping of the well. If one knew the direction from which the ground water flowed to the well, it could be shown perfectly simply, both

theoretically and by actual experimental tests, that pollution could come from enormous distances extending far beyond the so-called circle of influence. Common sense alone, from a visit to the ground, might mislead very greatly. It was possible also to have pollution quite close to a well yet not affecting it, even though the strata were perfectly porous and homogeneous.

Mr. W. R. Baldwin-Wiseman thanked the author for his paper. He said that his attention had been caught by the following sentence on page 167 " We are prepared to do away with every soakage pit or cesspit in the country ; we are prepared to purify all sewage discharged at outfall works up to any degree of chemical or bacterial purity required." He agreed that, as engineers, they were prepared to do what the author mentioned and would probably welcome the opportunity, but he questioned whether the people who would have to pay for all this work would agree to find sufficient funds for the purpose. There was need for the doing of a great deal of work by engineers in the improvement of the present state of sanitation and water administration, and especially in the collection of data ; but the great trouble was to find the money to do the work, which all agreed should be done ; he had been studying the records of the subject, and he found that over 60 years ago the first people (the General Board of Health—the predecessors of the Local Government Board) to suggest that the water supplies of the country should be looked into, asked the Treasury for a trivial grantof £300 for the purposes of investigating the water resources of certain geological formations in Surrey with a view to supplying London therefrom, but despite a most persuasive report the Treasury did not grant the money. Since that time Royal Commissions, Select Committees, and private individuals by the dozen, have urged that something should be done in measuring up the water supplies of the country and in mitigating the frightful waste of time, money and water under the existing conditions, but the " something " had always been rather general and not precisely defined. Sometimes it had been floods, sometimes sewage, and sometimes water supply, that had given rise to the suggestion, but the Government had turned a deaf ear to the requests which had been made, and other matters of much less economic importance have taken the lead. The Royal Commission on Sewage Disposal has been sitting for a number of years, and it has turned out a considerable mass of data in numerous reports, in three or four of which the Commissioners have emphasised the fact that something must be done in much more precise terms than formerly, but still nothing has been done up to the present.

In a reply to a discussion in the House, on the Poor Law Administration on April 27th, the Right Hon. John Burns said

"give him facts, feed him with facts, they were the only things that influence life," and quoting Robbie Burns, concluded "facts are chiels that winna ding." If engineers, whether interested in water supply, sewage disposal, or flood prevention, were to take this to heart and were to combine their forces, and press upon the authorities of the day the urgent necessity of dealing with the questions in which they were professionally interested, and were to back up those representations with an adequate supply of facts, they would have much more success than they had had hitherto. It should be seen to that Mr. Burns got the facts with regard to an improvement in the present involved condition of water administration and then doubtless a move towards its betterment would soon be inaugurated.

At the beginning of the paper the author said, "There are many instances of persons consuming badly polluted water during long periods without any recorded ill-effect." He (the speaker) thought that the personal equation should be considered as having an important bearing on this point. If a city-bred man consumed the country labourer's meal of pork and beans the result would in all probability be an acute attack of indigestion, and so it was with regard to the purity or otherwise of the water, the sturdy open-air life of the country assisting the body to resist disease, whilst the aids to locomotion and the confined existence incidental to town life predisposed it in a contrary direction ; he knew a little stream in Yorkshire from which the people got their water in the early morning, because, as a labourer told him, it was cleaner then as the cows stood in it for the greater part of the day, and the water was unpleasant after the cows had got there. The people seemed healthy and the village had a good record of immunity from disease. He was once investigating the water supply of a small place, and he found all the people antagonistic to any scheme of improvement. All they had was two pretty little brooks which were very badly polluted and the conditions were such as to call for immediate improvement, but somebody had been round before him and had told the people that if anything was done a sixpenny rate would have to be levied to pay for the improvement and the prospect of that not only extinguished any enthusiasm for a piped supply but rendered them all extremely hostile to any such scheme.

With regard to the paragraph on page 160 it had struck him that as sunlight had a bactericidal effect to a slight depth below the surface of water, that sunlight might have a much more decided beneficial effect on shallow moorland streams, such as not infrequently supplied reservoirs, than in the case of the deeper waters of lowland rivers.

Mr. W. Whitaker thought that the author was a bold man to tackle such a difficult subject. In the first place there was a difficulty about the title of the paper. What was meant by "protection of water-supplies"? His experience was that very different things were meant by that term. In the course of last session there was a bill before Parliament entitled "The Water Supplies Protection Bill." A characteristic of that Bill was that it did not protect any water-supplies at all, or any public ones, at all events. Possibly, if carried, it might have protected some private supplies at the expense of public ones. There was nothing in the Bill which in the least dealt with the protection of any water supply from pollution, the sense in which the author had used the term, but that was not the only protection which had come before engineers.

He should like to correct one statement of the author, who said that the Cambridge supply was far removed from any obvious source of pollution. It might be so; but that certainly was not the opinion of its opponents, who seemed to have convinced the inspectors of the Local Government Board that the source of pollution, if any, was not far off.

When engineers spoke about the protection of water supplies from pollution, a difficulty arose. What did they mean by "pollution"? The author, with great care and deliberation, had collected together a mass of opinions from different people, and had most conclusively shown that doctors differed very much indeed. What one man considered to be pollution another man did not.

He agreed with the remark of a previous speaker that any attempt to set up a definite standard was doomed to failure. It was impossible to judge a well-water by the standard which one would propose for river-water, and it was even impossible to judge a shallow well-water or spring-water by the standard which one would propose for a deep well-water. There were a great many things to be considered before any attempt was made to set up any strict standard. He objected to rules, and thought that they often rather retarded the work of the engineer. They were all very well in many cases; but there came a time when they might stop a very good piece of work which did not exactly conform to the standard set up.

The Bill to which he had alluded was concerned with a totally different sort of protection from that with which the paper dealt. It was the protection of water-supplies from one another. That matter ought to be considered. It was really a very important question, if a water-supply of any kind was established in a district and then another well, or other work was made, close by, and interfered with the former. The second authority or person might say, "I have as much right

to the water as you have," and it was a very difficult thing to prove that he was right or that he was wrong. The subject was one which engineers should tackle. It was certainly coming to the front.

He was inclined to think that the best test of whether a water was polluted or not was what he might call uncommon sense, or simple sense. While the chemist and the bacteriologist might fail to point out that the water was polluted, or stood risk of pollution, the keen observer, trained to see things properly, would hardly ever fail to detect that there was a risk of pollution. He had to study not merely the site itself, but its surroundings, sometimes to a considerable distance. A proper study of the surroundings would enable a man to tell as well as anything else would, whether there was risk of pollution. No opinion should be given by an engineer, a chemist, a bacteriologist, or even a geologist, without a thorough understanding of the surroundings of the works. A water which did not give a good analysis might really be much safer than another water which gave a fairly good one.

Mr. Percy Griffith said that he agreed with Mr. Whitaker that the title was rather misleading. It hardly went far enough to indicate the author's meaning. He had two alternatives to offer, "The Protection of Water Consumers from Water-borne Disease," or "The Protection of Water Engineers from Analysts." On the latter point the analysts had confessed their inability to comply with the author's request, which to some extent left engineers where they were, except for the assurance that they would do their best by further research to supply what engineers asked for.

He suggested that the author had been very unselfish in asking for a solution of the present difficulties because, after all, so long as analysts continued to add to the things which were necessary to maintain and increase the purity of water supplies, so long would engineers have ample employment. He knew one case where an expenditure of £200,000 was involved. To his knowledge a good scheme could have been provided for half the money, but what was said was that the public would not be satisfied unless a monumental expenditure was undertaken. The fact was that there had been an epidemic, and those who had charge of the undertaking considered (no doubt rightly) that the public would not be satisfied unless a very large sum of money was spent. He knew another case in which a large sum of money was expended in filters as to the necessity of which there were grave doubts, but the undertakers were a company, and they felt that their duty to the public and to their local authority required the spending of money in providing

further protection. He thought that, on the whole, water engineers might congratulate themselves upon being, as the author rightly said, able to cope with any circumstances which might be brought to them and any conditions which the analyst might impose.

In his own experience he had had cases of difficulty with regard to the quality of the water, and he had found at least four alternative courses which might be adopted. The first was in the case of receiving an unsatisfactory report of one sample, to get another sample and another report. If that failed the next alternative was to get another analyst. That would, very often (he thought that he might say too often) secure the desired result. The other two alternatives were both very serious. They might either have to get another source of supply (or spend a lot of money in entirely altering the character of what they had got), or they might be under the sad necessity of getting another engineer.

He thought that engineers, as a profession, were very unselfish in asking the analyst to give them a definite standard of purification, seeing that, if they had such a standard, it would much reduce the work to be done by water engineers generally.

Mr. C. T. Walrond said that he had had rather a peculiar experience. The circumstances were as follows. There was a private spring of water in a park, supplying a large house in the country, and a tap outside the town hall, a little distance off, was fed from the same spring. For some reason or other, the Town Council thought that there might be some danger in the water, and they sent a sample of it to a very eminent chemist and asked him for his report. He condemned the water, and the tap outside the town hall was promptly removed. A month or two afterwards the same chemist had a sample sent him from the same water supplying the large house. He reported upon the water, and said that it was all right. There would not have been much to say about that if he had not given his reasons. Unfortunately, he condemned the first sample on account of the large amount of nitrates in it, passed the second sample which contained a larger amount of nitrates still, and stated the figures in each case. That landed him (the speaker) in some little difficulty. He had been impressing the value of water analysis upon his client who lived in the house which obtained its supply of water from the spring in the park, but when this inconsistency of the eminent analyst came up his client merely remarked that he was not in the least surprised. There ought to be standards sufficient in capable hands to prevent mistakes of this kind.

Mr. J. Mackworth Wood said that Mr. Whitaker had told him that he ought to say a word or two on the protection from pollution of two water supplies for which he (the speaker) had been responsible. They were large gravel supplies in the Eastern Counties. He had adopted the position of taking precautions more than anything else. In one case they took something like 400,000 gallons in 24 hours from a bed of glacial gravel overlying the London clay, this being the natural yield of the springs. The gravel bed was in an agricultural district of some 12 square miles in area. The springs come out to the surface on the London clay. In carrying out the works they had cut back and put in perforated stoneware collecting pipes well at the back of each of the springs. Fine shingle was then packed in by hand around the pipes, and the trench filled up with the material in the order it was excavated. Then they had enclosed the springs with unclimbable fencing within a considerable area of land, and absolutely prohibited man's approach to the springs. In addition to that, they had taken a very large area of land some 30 acres at the back of the springs in the direction the water was flowing and kept out all forms of grazing. So the springs were doubly secured against pollution by an inner and outer zone of protection. The water was periodically examined chemically and bacteriologically.

In another supply from a bed of gravel overlying the crag with which he had dealt, he had taken the same precautions by enclosing a large area of land, about 12 acres, within barbed wire fencing, so that it was like a Boer camp, and the wells and gathering pipes within the larger enclosure were again further enclosed. No pollution by man could possibly take place on the site except wilfully. The only matter which had troubled him, so far as the protection of the site was concerned, had been the British landowner. He was a great bugbear in connection with obtaining the necessary land for protection purposes. When these works were started, an area of land sufficient only for the work was taken ; then the chemist comes along and draws one's attention to the bacteriological condition of the water, and the need of land for further protection. Having no parliamentary powers to acquire land compulsorily, one had to approach the rapacious landowner in order to get the increased area for proper protection. For land which was let at 7/6 per acre per annum for sheep grazing, one ultimately had to pay £120 an acre. That sort of thing, of course, made it very difficult to efficiently protect small water undertakings to any great extent.

Not being a bacteriologist he was much alarmed last year to receive a telegram informing him that this particular water supply, which was so well protected, had got much polluted.

He immediately investigated the matter with the assistance of an eminent chemist. The chemist said he was certain that the water was polluted, somehow or other. He (the speaker) was equally certain it was not polluted by man, neither could he at first make out where the pollution came from. The soil of the enclosed land was very sandy, and the only animals which could get access thereto were rabbits and these were present in some numbers.

As is well known, rabbits congregate, when at play, on any mound or prominence, and leave their droppings and urine thereon. The covers over the pits at the heads of the collecting pipes, stood some 4in. to 6in. above the ground and were air tight, but the only cover to the well, also about 4in. above ground surface, was not air tight, being formed of chequer plates with butt joints, through which the coli could pass. Samples of water were taken for chemical and bacteriological examination, probably from the surface of the water in the well instead of from the bottom, but previous to taking the sample, the cover had been thoroughly swept, before unscrewing the plates, with the result that dust and coli had fallen through the joints into the water in the well. As soon as the so-called coli pollution had been established, the source was pumped for several days and fresh samples taken, but not a trace of coli could be found. This shews how easily a source can be polluted with B. coli.

Reply.

The Author, before replying to the discussion, said that he wished to make a further comment upon a sentence upon page 162 of his paper, to which Dr. Houston had taken exception. Dr. Houston's official position made it impossible for him to take part in discussions on papers, and so he was unable to appear personally to reply to a comment made upon his report, which was as follows :—

> "It is therefore surprising to find that Dr. Houston, in a recent report, actually suggested as a proof of purity the fact that he personally had consumed a certain quantity of water known to have been infected with typhoid germs originally."

Dr. Houston was of opinion that the author had misunderstood his views, and had therefore failed to express them properly. The report in question was primarily directed towards showing that uncultivated typhoid bacilli were apparently less hardy than cultivated bacilli ; the drinking experiment was merely an incident. The actual words in Dr. Houston's report were as follows :—

> "Obviously the infected water was not drunk owing to any feeling of dissatisfaction with the laboratory evidence of the death of the typhoid bacillus. But there are many persons who do not understand bacteriology, and there may be others who mistrust its findings. To these persons, and perhaps people in general, a drinking experiment is much more conclusive evidence of 'safety' than any negative results obtained in the laboratory."

As Dr. Houston was unable to discuss the point, the author must refrain from making any statement, further than that he hoped that he had now removed any incorrect impression produced by the wording of his paper.

In reply to the discussion, the author thanked those present for the very kind way in which they had received and discussed his paper. It was rather surprising, he thought, that a meeting of engineers, chemists and bacteriologists should practically come to an agreement that they knew nothing about the pollution of water supplies. They could not even agree as to whether crude sewage in water would cause disease. It appeared that there was a difference of opinion on almost every point. He thought that the chemist and the bacteriologist were scarcely fair to themselves. He knew that they would tell a very different story next time he was called up to prove by "common sense" that the water in his well was pure, and they on the other side wished to prove by scientific demonstration that it was impure. He gathered from remarks made that, upon the whole, those present agreed that coli were a danger signal but that the scientist would do wrong in demanding their exclusion in all cases, because there was nothing to show that they always indicated danger; but this argument appeared to him to be very much like saying that if water was badly discoloured it by no means proved that it was dangerous. The discoloration might be harmless, and even beneficial, but for all that, the people of England had adopted a standard for themselves, and would not drink water which was discoloured, preferring to err on the side of safety, and if they could also see the coli organisms and knew that they were danger signals, they would also have adopted a further standard for themselves and refused to drink any water that contained these danger signals.

There was only one logical reason for not demanding absence of coli from waters of all kinds, and that was in his opinion due to a misapprehension. It did not matter from what source a water was obtained; the coli could be removed and the work of removal was so simple and so cheap that its cost could not be urged against it. Those who urged that it would be expensive to

sterilize water or sewage effluent merely displayed their want of knowledge of what was being done at the present time. If coli were danger signals, the bacteriologist would be quite reasonable in demanding their absence. If they were not danger signals, or if he were ready to acquiesce in their presence merely because human pollution could not be proved, his evidence was obviously of very little value, and the work of the bacteriologist might be omitted without any serious loss.

If a water contained coli, the bacteriologist had no positive proof that there were not danger signals, and he admitted it, and why he asked them to accept water containing these danger signals, after proving them to be such, was very difficult to understand. It was apparently merely due to his kindness of heart in not wishing to burden the ratepayer with the cost of such works as would be required in order to remove the objectionable organisms, but this leniency on his part was quite misplaced, seeing that the engineer was quite ready to construct works which would remove the coli, and that the cost of these works was not great. The fact that animal pollution was assumed to be harmless, still seemed to the author to be merely a pious opinion. There was no proof that this was the case. All they knew was that scientists had hitherto apparently failed to prove that such pollution was dangerous, but there perhaps they might come back to the quality so much advocated in the discussion, viz., common sense.

With regard to Professor McWeeney's doubts as to the harmlessness of coli, the author could only refer him to Professor Starkey's paper, read upon the subject before the Leeds Congress, in which very clear evidence was given upon that point, and in the face of such evidence it was difficult to see how anyone could assume that coli were as harmless as had generally been believed ; furthermore, recent results quoted by Dr. Rideal clearly showed that water had an important bearing upon the prevalence of a good many diseases hitherto considered to be quite out of the question, a point which supported Professor Starkey's contention.

Mr. Baldwin-Wiseman had pointed out the slowness with which money required for necessary works was forthcoming, but was this surprising in the face of the fact that the scientists would not agree even upon the most elementary points ? If the bacteriologist, the chemist and the engineer would look matters in the face and come to an agreement, they could insist upon an enormous amount of necessary work being done, which would be of great advantage to the public. If the chemist

and bacteriologist persisted in their present hesitating and double-minded attitude, they would simply prove the uselessness of their evidence, and they would be superseded by water examiners whose qualifications would be "common sense" and force of character, which, in the author's opinion, would be a retrograde step.

CORRESPONDENCE ON PROTECTION OF WATER SUPPLIES.

Mr. Diogo A. Symons writes as follows :—" I have read Mr. Shenton's paper with great interest and consider the subject matter is of great importance to all engineers practising in this branch of the profession. I am, however, of opinion that the paper, as a means of discussion, is more for the chemist to express his views, than the engineer.

The engineer from experience should be in a position to state from geological and other conditions where water can be obtained and if it will be sufficient for a particular purpose, but the quality of the water must obviously be left to the chemist, although in some instances the conditions are such that it is apparent to the engineer that pollution will take place. The question of obtaining a good pure water supply is of such importance that no money should be spared for remedial measures when necessary, and it certainly appears to me that a standard basis of analysis should be strictly adhered to.

I quite agree that there are many instances of persons consuming polluted water without any ill-effect, but this is no doubt due to the persons being in good health at the time, and to the degree of pollution not being excessive, but I consider that if pollution is present to any great degree, the chances are that the consumers will be infected, quite regardless of their state of health, and it is consequently of paramount importance that no effort should be spared to remedy the defects and obtain water of a thoroughly pure quality.

What this standard of purity should be, is a matter for the chemist, but it appears to me that in all instances a standard of purity should be set up. I fear that in many instances contaminated water has been allowed to be used, because no ill-effects have arisen, and on account of the expense involved in 'putting right.' I consider this to be a short-sighted policy and we ought to remember the old saying that prevention is better than cure."

VISIT TO THE FESTIVAL OF EMPIRE BUILDINGS AT THE CRYSTAL PALACE.

By kind permission of the Council of the Festival of Empire, a party of members of the Society of Engineers (Incorporated) and their friends, numbering nearly 100, visited the Crystal Palace on Saturday, May 6th, 1911, to inspect the building works in progress. Mr. Burnard Geen, A.M.I.C.E., M.S.E., consulting engineer to the Council, explained the chief points of interest. The visitors were first shown the two new reinforced concrete staircases leading from the main floor level of the Centre Transept to the first terrace. The surface of all steps and landings is finished with 1in. granolithic, put on at the same time as the main body of concrete. The concrete was hand mixed, was composed of washed shingle varying in size from $\frac{3}{4}$in. to $\frac{1}{8}$in., washed sand of a sharp nature, varying in size from $\frac{1}{8}$in. downward, and Portland cement, in the proportions of 27 cubic feet of shingle to $13\frac{1}{2}$ cubic feet of sand to $6\frac{1}{2}$cwt. of cement. The whole of the work, consisting of some 325 cubic yards of concrete, was completed in about eleven weeks.

The next work of interest was the strengthening to the existing roof of the Indian Section, a polygonal-shaped building with sixteen sides. The existing iron domed roof, with a fixed span of 123ft. 6in. and a rise of 27ft., built thirty years ago, was found to be in bad repair, and in order to carry the new false dome of fibrous plaster, supported on timber framework, which it was decided to add, it was necessary to truss the existing ribs. Scaffolding was erected from below, and the closing members of the new steel trusses were put in with initial tension, so as to relieve the existing ribs of dome action and convert them into compression members of the new trusses.

At the main entrance to this building there is a drop of no less than 10ft., which has been got over by a flight of thirteen steps leading down to a raised platform 3ft. 6in. high above the main floor of the building, 12ft. wide and about 60ft. long, with a further seven steps at each side, thus converting a serious difficulty into a feature of the building.

Passing out into the grounds again the party had a good view of the various features of the exhibition, and inspected the buildings for housing the exhibits from South Africa, New Zea-

land and Australia. These latter buildings are models to three-quarter full size of the parliament houses of the respective Colonies, and have an area collectively of about 6,500 super. yards. They are constructed of timber covered with fibrous plaster, painted so as to take the appearance as far as possible of the stonework of which the originals are constructed.

After seeing the various other attractions of the exhibition tea was served in the Palace, and ended a very enjoyable and instructive visit.

ANNUAL DINNER.

May 27th, 1911.

The Annual Dinner, which was well attended, was held at the Criterion Restaurant on Saturday, May 27th, the chair being taken by the President, Mr. F. G. Bloyd. Among the guests were Mr. Alexander Siemens (Hon. Fellow), President of the Institution of Civil Engineers ; Mr. E. B. Ellington, President of the Institution of Mechanical Engineers ; Sir David Gill, K.C.B., F.R.S. ; Professor John Perry, F.R.S. ; Prof. C. Vernon Boys, F.R.S. ; Mr. J. W. Jacomb-Hood, Engineer-in-chief to the L. & S.W.R. ; and a number of ladies, including Miss Alice J. Perry, B.E. (Roy. Univ. Ireland), who was for some time Acting County Surveyor for Galway, and is probably the only lady holding an engineering degree.

The loyal toasts having been honoured, Mr. Alexander Siemens, proposing the toast of "The Society," said that the Society of Engineers (Incorporated) was an amalgamation of two older societies, one of which—the Civil and Mechanical Engineers' Society—had, before its inception in 1854, asked the Institution of Civil Engineers to grant certain privileges to students, which request the Institution refused, whereupon the students formed a society for themselves under the name above mentioned. He (the speaker) thought that, as the Society was always ready to look after the proper interests of engineers, it ought to be encouraged.

The President, in reply, said that a compliment from such a quarter was a compliment indeed. The Society had no wish to be in antagonism with other engineering bodies, but rather desired to co-operate with them as far as possible. With regard to the encouragement of the junior engineer, the Society had initiated a scheme for the affiliation of student engineering societies, which would do a good deal to assist junior men ; and if they could do anything else to help the younger members of the profession they would be very glad.

The toast of "The Ladies" was proposed by Mr. E. B. Ellington, and a reply on behalf of the ladies was given in appropriate terms by Mr. J. W. Jacomb-Hood.

At the conclusion of the speeches, which were brief, an adjournment was made for the concert, which was given under the direction of Mr. Charles Capper. Coffee was served at small tables, and the formality usually inseparable from a dinner was therefore done away with, the members grouping themselves as they chose. The musical programme, which was longer than usual, was much appreciated, and made a suitable ending to a most enjoyable evening.

VISIT TO THE LIVERPOOL STREET EXTENSION OF THE CENTRAL LONDON RAILWAY.

The second vacation visit of the present session took place on Thursday, June 8th, 1911, when, by the courtesy of the engineers, a party of members of the Society and their friends were privileged to inspect the works in progress in connection with the extension of the Central London Railway from the Bank Station to Liverpool Street. The work of driving the tunnels is being carried out from a shaft in Bishopsgate, near Acorn Street, and will be continued up to the junction with the company's existing sidings at the Bank.

The small running tunnels are 12ft. 5in. internal diameter, each ring being 20in. wide with 4in. flanges, and are made up of four radial-jointed cast-iron segments, two top segments and a key whose sides taper slightly in the reverse direction to the keystone of an arch; this admits of ease in erection. The joints between the flanges of adjacent rings and segments are formed of creosoted wood packings and are bolted together in such a way that the horizontal joints of one ring break joint with its neighbours. The weight of each ring is 33.4 cwt. Under ordinary conditions nine rings or five lineal yards of tunnel are built every twenty-four hours. The shield by which these tunnels are driven consists of a cast-iron or steel cutting edge, followed by a skin of ¾in. steel plates, butt jointed, which are kept to the cylindrical form by means of suitable strengthened segments and girders, well bolted and riveted together. Forward movement is obtained by means of 7in. diameter hydraulic rams, eight in number, disposed round the inside of the skin and arranged

so that the tongues press against the iron lining already built. These rams are controlled individually or collectively by a set of valves, so that by a suitable combination the direction of the shield may be guided. The maximum pressure available is 2,000 pounds per square inch, which gives a total maximum push of 275 tons.

In the case of the 21ft. 2½in. internal diameter station tunnel, the shield is on the same principle as that just described, and the method of procedure in construction is the same. There are twenty-two rams of 7⅛in. diameter, each capable of exerting a total force of forty tons as a maximum, and hydraulic erectors are used in place of hand erection for the cast-iron segments. The rings of this tunnel are 18in. wide, with 6⅝in. flanges, and consist of ten radial segments, two top segments and a key. The horizontal joints are machined true to radius, but the vertical joints are made with creosoted wood packings. The weight of each ring is 4⅛ tons, and the anticipated progress is about five rings or 2½ lineal yards per day of twenty-four hours.

The plant at the site of the working shaft consists of two 3-ton cranes for dealing with materials to and from the tunnels, and the following compressors for supplying compressed air to the tunnels and for operating the pneumatic-hydraulic pumps and grouting pans : One vertical compressor with one cylinder 19in. diameter, 8in. stroke, and three Reavels compressors each having eight cylinders, 12in. diameter and 6in. stroke. One of these latter works against a pressure of 15lb. per square inch, the other two are two-stage machines and work against a pressure of 60lb. per square inch. There is also a compressor by Ingersoll, measuring 18in. by 18⅛in., and an hydraulic intensifier converting a pressure of 750lb. per square inch to one of 1 ton per square inch.

The contractors for the work are Messrs. John Mowlem and Co., and the engineers to the Central London Railway Co. are Messrs. Mott and Hay, of Westminster, for whom Mr. H. J. Deane acts as resident engineer.

THE PROMOTION AND CONSTRUCTION OF THE LONDON AND BIRMINGHAM RAILWAY.

By F. G. BLOYD (President).

If any apology were necessary for the contribution to the Society's Journal of a description of a work that was executed over seventy years ago, the action would be capable of justification on more than one head.

In the first place, the consideration, however cursory, of a work that, in more modern days, can lay good claim to be regarded as a pioneer in its own special branch of engineering, should furnish some ground for profitable thought, since, despite the great advance made in the more recent practice of every phase of the profession, there are often lessons to be learnt from the works carried out during the earlier stages of the same, many of which works still stand to-day and serve as appropriate examples of the skill and foresight displayed by those responsible for their design and construction.

If a second reason were required, the plea is made that it is desired specially to bring forward during the present year a few of the many points embraced in the wide field of railway construction and equipment, and a cordial appeal is extended to further that object.

Turning now to the promotion of the original London and Birmingham Railway; surveys had been made as far back as 1823 for a line between these two points, but it was not until the Liverpool and Manchester line was nearing completion that the project was matured. In 1830 two schemes were prepared, one by Sir John Rennie, which followed a route through Oxford and Banbury, and the other by Mr. Giles, which passed through Coventry. Rival companies were formed to support the two proposals, but wiser counsels prevailed before a Parliamentary contest was reached, and the companies joined hands to promote what should ultimately be found to be the best route for the railway. George Stephenson had already been engaged by the parties favouring the Coventry route, and, as he also supported that scheme, it was decided to adopt the Coventry route, and George Stephenson and his son were nominated engineers to the company.

In determining the actual location of the line, many problems presented themselves to the engineers, the chief object, next to securing a good traffic route, being to select a line on which favourable gradients could be obtained, together with

due economy in construction. On this latter point it may be remarked that the country traversed by the proposed line consists of a sequence of valleys or low districts divided by ranges of hills, the lower districts consisting of the London basin, the valley of the river Colne, extending from Brentford by Watford to St. Albans, the basin of the river Ouse near Stoney Stratford, the valley of the Nen, the basin of the Avon and the basin at Birmingham, the intermediate summits occurring at Oxhey, Tring, Blisworth, Kilsby and Meriden.

Mr. Robert Stephenson, upon whom the work of location principally devolved, was instructed to prepare plans for deposit in the autumn of 1830, but, although the Parliamentary Standing Orders were not then so strict, it was found that the time available was not sufficient and the deposit was postponed until the following year. The plans, as deposited in November 1831, provided for a double line of railway commencing at Camden Town and passing by way of Watford, Berkhamstead, Leighton Buzzard, and Coventry, the steepest gradient being 1 in 330, or 16ft. per mile, the Parliamentary estimate being as follows :—

	£
Excavations and embankments	779,000
Tunnelling	250,286
Masonry	350,574
Rails, chairs, keys and pins	212,940
Blocks and sleepers	102,960
Ballasting and laying rails	102,960
Fencing at £740 per mile	76,032
	£1,874,752
Land	250,000
Six water stations at £500	3,000
Six intermediate pumps	600
Offices, etc., at each end of the line for convenience of passengers, etc. and walling for enclosing the space for depôt ..	16,000
Forty locomotive engines, £1,000	40,000
Three hundred waggons, £30	9,000
Sixty coaches, £200	12,000
	£2,205,352
Contingencies	294,648
	£2,500,000

The average cost per route mile of railway, including working stock, but excluding stations, was thus about £21,756.

The estimated gross value of the traffic on the railway was originally placed at £671,102 per annum, which estimate was

increased by Mr. Stephenson in 1837 to £1,285,965, the expenses being calculated at one-half of the receipts.

The first-named traffic estimate was not a lightly considered figure, but was carefully based on a schedule taken of the number of persons carried in the coaches and other vehicles using the direct road between the two towns during a period of one fortnight, the Stamp Office returns being utilized for the remainder of the coaching which could not be counted, the whole of the results being taken into a tabular statement, which is set forth herein.

The Bill was read a first time in the House of Commons on February 20th, 1832 and a second time on February 28th, after a division of 125 to 146. The Committee stage was reached on April 5th and continued until April 13th, when it was adjourned to May 21st, and on June 5th the Committee passed the project, the third reading in the Commons being on June 19th, 1832.

The measure was read for the first time in the House of Lords on the same date, the second reading taking place three days later. No division ensued on either reading, and the Bill passed into Committee, which spent seven days in discussing the matter.

The evidence tendered in favour of the railway completely overshadowed the opposition raised against it, the latter being almost entirely confined to cross-examination of witnesses and not advancing any real points of objection ; but, notwithstanding this, the Bill was thrown out on the plea that the promoters had not made out such a case as would warrant the forcing of the proposed railway through the land and property of so great a proportion of dissentient landowners.

The Directors renewed their application to Parliament in November 1832, the plans being almost identical with those of the previous session, the only changes being a slight diversion of the route between London and Harrow and the alteration of the site of the London terminus to a spot on the Hampstead Road where the Camden Town Station now stands. The Bill passed the Commons' Committee on March 15th, 1833, and the Lords' Committee on April 22nd, receiving Royal Assent on May 6th, 1833, the expense of obtaining the Act being £72,868 18s. 10d.

By the Act of Incorporation the Company were authorised to raise £2,500,000 in shares and £835,000 by loan.

The first three contracts, covering twenty-one miles of railway near London, were let on April 21st, 1834, and in August of the same year a further length of twenty-one miles next to Birmingham was also let, but it was nearly two years before the whole of the contracts were settled.

As previously stated, the London terminus of the railway was originally planned at Camden Town, but, with a view to bringing the passenger traffic nearer the Metropolis and more

effectually separating passenger from goods traffic, the company obtained a further Act in 1835 authorising the extension of the line to the present terminus at Euston, this latter length of railway being laid with four lines of rails, and worked for some years by stationary engines.

Between 1834 and 1837 strenuous efforts were made to expedite the works, but from the very outset considerable difficulties were experienced, and seven of the heaviest contracts were thrown on the company's hands, necessitating the purchase of plant and other unforeseen expenses.

Among these contracts were those for the tunnels at Primrose Hill and Kilsby and the long cutting at Blisworth, which was, perhaps, the most trying piece of excavation on the railway, owing to the unexpected presence of deep beds of clay underneath the surface rocks. Beds of loose shale, mixed with large quantities of water, were also met with and before the cutting was completed almost a million cubic yards of material had been removed. In regard to the tunnels, the difficulties that were encountered can, perhaps, be more easily realised, especially when it is borne in mind that the knowledge of this always uncertain phase of engineering was far more limited in those days than is the case at the present time.

In his evidence before the Lords' Committee in 1832, Mr. Stephenson stated he estimated the cost of the Primrose Hill, Watford, Brockall, Kilsby and Becknell Tunnels at £32 per yard run, and the shorter tunnels which did not require ventilating shafts at £26 per yard run. In all cases 18ins. of brickwork were provided for. At Kilsby Tunnel, which is 2,426 yards in length, operations were commenced by the contractor in June, 1835, but the initial stages of the work quite upset all the original calculations, and in March, 1836, the contract was given up, the company being left to continue the work.

Trial shafts had been previously sunk along the line of the tunnel to determine the nature of the ground, and showed the substratum to be generally lias shale with a few beds of rock, dry in some places, but containing large quantities of water in others. When, however, the second working shaft was sunk, a bed of sand and gravel containing water was discovered, which proved to be a perfect quicksand, and quite precluded the shaft being carried through by ordinary means. Other borings revealed the fact that this bed of sand extended over the line of the tunnel for a length of about 450 yards and was shaped like a flat bottomed basin, the lowest portion of which dipped to a level about six feet below that of the crown of the arch. The original trial shafts had been sunk on either side of this basin, so that its existence was not known until the working shaft reached it. After due consideration it was decided to pump the water out of the basin, the operation being continued

for nine months before it was found possible to proceed with the construction of the tunnel.

The first of the large ventilating shafts, over 60ft. in diameter and 132ft. deep, was commenced in May, 1836, and finished in about twelve months, the second shaft being about 100ft. in depth. These shafts were constructed in brickwork, three feet thick, laid entirely in Roman cement, and were carried down in lengths of 10ft.

In November 1836, a large inrush of water occurred in a portion of the tunnel where no pumps were placed, and in order to prevent damage resulting to the excavation at the end of the length, it was found necessary to provide a large raft upon which men and materials were floated along the tunnel to the spot, and the brickwork completed at some considerable risk of life.

The tunnel was eventually finished in October, 1838, having cost over £300,000, or upwards of £130 per lineal yard. The original contract price for the work was £99,000, or about £40 per yard. At Primrose Hill the thickness of the brickwork had to be materially increased in consequence of the great pressure exerted by the clay swelling when exposed to the atmosphere, and at Watford Tunnel the chalk formation was found to contain fissures filled with sand and gravel which greatly impeded the work, but this latter tunnel was successfully completed by the Contractor, the total cost being about £140,000, or about £78 per lineal yard.

The large additional expenditure on the railway necessitated further application to Parliament for extra capital, a sum of £1,000,000 being authorised by the Act of 1837, and a like amount by the Act of 1839.

The railway was opened for traffic between London and Boxmoor, a distance of about 24½ miles, in July, 1837. In the following October the opening was extended to Tring, and in April, 1838, passengers were conveyed through from London to Birmingham, a distance of 35 miles between Denbigh Hall and Rugby being performed by coach.

On September 20th the line was entirely opened, and the Company's trains ran from end to end.

The completion of the railway constituted an event of almost national importance, and redounded to the credit of the gifted engineer who had planned and supervised the work, and also of the Directors of the Company for their perseverance and sound policy in meeting the various difficulties which they were called on to surmount.

The first public train between the two terminal stations is said to have run on September 17th, 1838, and, as an interesting camparison with present-day conditions, the time-table of the run may be given.

Euston	dep.	8.10 a.m.
Camden	,,	8.25 ,,
Watford	,,	8.48 ,,
Tring	,,	9.23 ,,
Wolverton	,,	10.28 ,,

Halt of 35 minutes to celebrate the completion of the railway.

Roade	dep.	11.16 a.m.
Rugby	,,	12.30 p.m.
Coventry	,,	1.6 ,,
Birmingham	arr.	1.50 ,,

The original station at Birmingham was situate in Curzon Street, adjoining that of the Grand Junction Railway Company, and, on the arrival of the above-mentioned train, the carriages were transferred to the latter railway and the journey was continued to Manchester, which was reached at 6.30 p.m. the same evening.

The total cost of the undertaking up to June 30th, 1840, is given in "Whishaw's Railways of Great Britain and Ireland" (published 1842) as under :—

	£	*s.*	*d.*
Land and compensation	706,152	5	2
Railway, works and stations ..	4,287,646	18	10
Engines, tools and implements ..	146,910	5	11
Coaches, trucks, waggons	189,187	4	5
Acts of Parliament	72,868	18	10
Law charges, conveyancing, engineering, direction and sundries ..	167,983	3	11
Interest on loans	127,493	0	6
Debenture charges	133	7	0
	£5,698,375	4	7

The report of the company presented at the General Meeting held in August, 1838, stated that the number of passengers carried during the half-year ending June 30th was 158,838. From January 1st to April 8th, when the railway was only open from London to Tring, the number of passengers was 36,024, the daily average being 244 for the whole 32 miles.

	£	*s.*	*d.*
The receipts were	7,271	13	2
The expenses	8,048	19	4

From April 9th, 1838 (the date of the opening to Denbigh Hall and Rugby), to June 30th the number was 122,814 and the daily average for the whole 77 miles was 715.

	£
The receipts were	41,322
The expenses	16,097

For the year ending June 30th, 1840 (when some further small extensions had been opened), the working results were as follows :—

	£
Receipts	687,104
Expenses	422,467

In his address to the Sheffield Meeting of the British Association in September last, Professor Dalby, President of the Engineering Section of the Association, formulated an interesting comparison between the working results of the London and Birmingham Railway for the year above quoted and those of the L. & N. W. Rly. for the year 1908, of which the following is an extract :—

"The gross receipts of the London and North Western Railway in 1908 were twenty-two and a half times as much as those of the London and Birmingham Railway in 1840, and the track-mileage open was about twenty-two times as great. The money earned per mile of track open is thus practically the same after a lapse of 70 years. To earn the same amount per mile of track open, however, the trains of the London and North Western Railway had in 1908 to run 68.3 times the number of train miles that the trains of the London and Birmingham Railway ran in 1840. That is to say, in order to earn a sovereign, a London and North Western train has now to run three times the distance which it was necessary for a London and Birmingham train to run to earn the same amount."

Another interesting feature of the company's accounts is that the cost of the initial working of the railway was computed on the ton-mile basis, a system that is now publicly adopted by only one railway company, although efforts have been made to ensure such a working return being compulsory; thus, for the year 1839, the total distance run by the passenger engines was 475,842 miles, an average of 12,201·76 miles per engine. The gross number of tons conveyed one mile amounted to 21,158,796 or 542,533·23 tons by each engine. The quantity of coke consumed was 18,229,232lb., or, on an average, at the rate of 0·86lb. per ton mile. The cost of the coke was £15,212, being equal to 37·38 shillings per ton, or 0·17 pence per ton mile.

During the same period the total mileage run by the goods engines was 239,156 miles, an average mileage per engine of 7,971.86 miles. The gross number of tons conveyed one mile was 17,527,439, or 584,247·96 tons per engine. The coke consumed amounted to 10,077,872lb., or, on an average, at the rate of 0·57lb. per ton mile. The cost of the coke was £8,343, or equal to 0·11 pence per ton mile.

Before leaving the mechanical equipment of the railway, reference may be made to the stationary engines originally

provided at Camden for hauling the trains from Euston, a Parliamentary restriction precluding the user of locomotives on that length in the first instance.

The two sets of engines, each of 60 h.p., together with the boilers, were placed beneath the railway on the north side of the Regent's Canal. The cylinders were 43in. diameter, the stroke being 4ft. A smaller engine of 6 h.p. was also provided for the purpose of exhausting the condenser, to assist in the immediate starting of the main engines on receiving the signal from Euston, which was done by means of a pneumatic telegraph.

The continuous rope was rather over 4,000 yards in length, 7in. in circumference and 11 tons 15 cwt. in weight. Its first cost was £476. In order to preserve the rope at its proper length and make allowance for variation in temperature, a horizontal tightening sheave, 12ft. in diameter, was fixed on a truck running on a short length of rails. At the north end of this truck was another rope, connected to a counter-weight which was suspended in a well having a total depth of 82ft. The time taken in hauling a train up the incline was from 3½ to 5 minutes, according to the weight, the distance being rather over one mile.

The original station at Euston occupied a space of about 5 acres, the departure and arrival platforms being each 200ft. in length and 16ft. in width, the whole being covered by an iron roof of equal length and of a total width of 80ft., divided into two spans.

Four lines of rails were laid between the two platforms, the whole of the lines being connected transversely by turntables at either end of the platforms, and also at a point opposite the entrance to the carriage depôt.

The original Curzon Street Station at Birmingham contained six lines of rails under the station roof, which was 233ft. in length and had two spans of 58ft. The arrival and departure platforms had a width of 20ft., turntables giving communication between all of the roads and also into the adjoining station of the Grand Junction Railway.

In addition to the two terminal stations, eight first class intermediate stations were provided at Watford, Tring, Leighton, Wolverton, Blisworth, Weedon, Rugby and Coventry, and a similar number of second class stations at Harrow, Boxmoor, Berkhampstead, Bletchley, Roade, Crick, Brandon and Hampton.

The principal goods depôts were at Camden Town and Birmingham, the central locomotive and Carriage Depot being established at Wolverton.

In "Whishaw's Railways" the cost of the original Euston Station is given at £81,532, that of the Camden depôt at £114,385 and the Wolverton Depôt at £109,454.

From a geological point of view the construction of the railway presented some attraction, as the depth of several of the cuttings permitted the various formations to be traced.

At Primrose Hill the London clay was passed through, while near the first summit at Oxhey the plastic clay and sands were well disclosed in the deep cutting there.

The chalk made its first appearance under the plastic clay near the river Colne at Watford and extended along the route of the railway to Tring, where the second summit occurs.

At the Watford and Northchurch tunnels a layer of gravel covered the upper chalk, in many places penetrating it and forming large pockets which caused great hindrance to the Watford Tunnel works.

Through the Tring cutting, two and a half miles long, the lower or grey chalk formation without flints was encountered, many impressions of fossils being found, also concretions of iron pyrites. Between the Tring summit and Leighton Buzzard, chalk, marl, green sand and weald clay were intersected in the shallow cuttings, and at Leighton Tunnel the iron sand formation, which occurred in cliffs and abrupt hills, was pierced.

The oolitic series were next crossed, and extended to the river Avon at Woolston, where the red marl or new red sandstone was intersected and continued to Birmingham, the sandstone rock being met in the excavation through the Meriden ridge.

Among the works of the railway which call for more detailed notice may be mentioned the bridge crossing the Regent's Canal, which had a clear span of 5f0t. between the abutments, the design of the structure being restricted from the fact that rail level was only 13ft. above the water line in the canal.

The bridge carried four lines of rails and had two outside cast iron bow string girders and a single central girder of similar design, two lines of rails being carried on each half.

The main girders consisted of two open ribs, cast in one piece for their entire length of 58ft., spaced 3ft. 8in. apart over all, and connected together by transverse cast iron bracing frames, placed 5ft. 10in. apart, from which the cross girders were suspended. The thrust on each of the two outside girders was taken up by four wrought iron tie-bolts, 3¼in. diameter, which formed the chord of the bow. In the case of the central girder eight tie-bolts were provided, divided into two groups of four bolts under each rib. The cast iron cross girders were of fish bellied form 28ft. long, 2ft. deep at their centres, and suspended from the bracing frames between the ribs of the main girders by wrought iron tie rods, 2½in. diameter.

The permanent way was laid on longitudinal oak timbers, resting on the cross girders, the depth of the substructure being 2ft. 10in. The design of this bridge, for which Mr. Fox, one of the resident engineers, is said to have been responsible, attracted

some attention at the time. A cross-section through the central girder of this bridge is shown on Plate 1.

Nearing Watford, the viaduct over the London Road contained five arches of 43ft. span, the centre arch being on the skew in order to preserve the original course of the road, and a second viaduct over the river Colne consisted of five arches of 30ft. span. Considerable trouble was experienced with the foundations for the latter. The Wolverton viaduct over the rivers Ouse and Tow contained six elliptical arched spans of 60ft., was of a total length of 660ft., and cost £28,000.

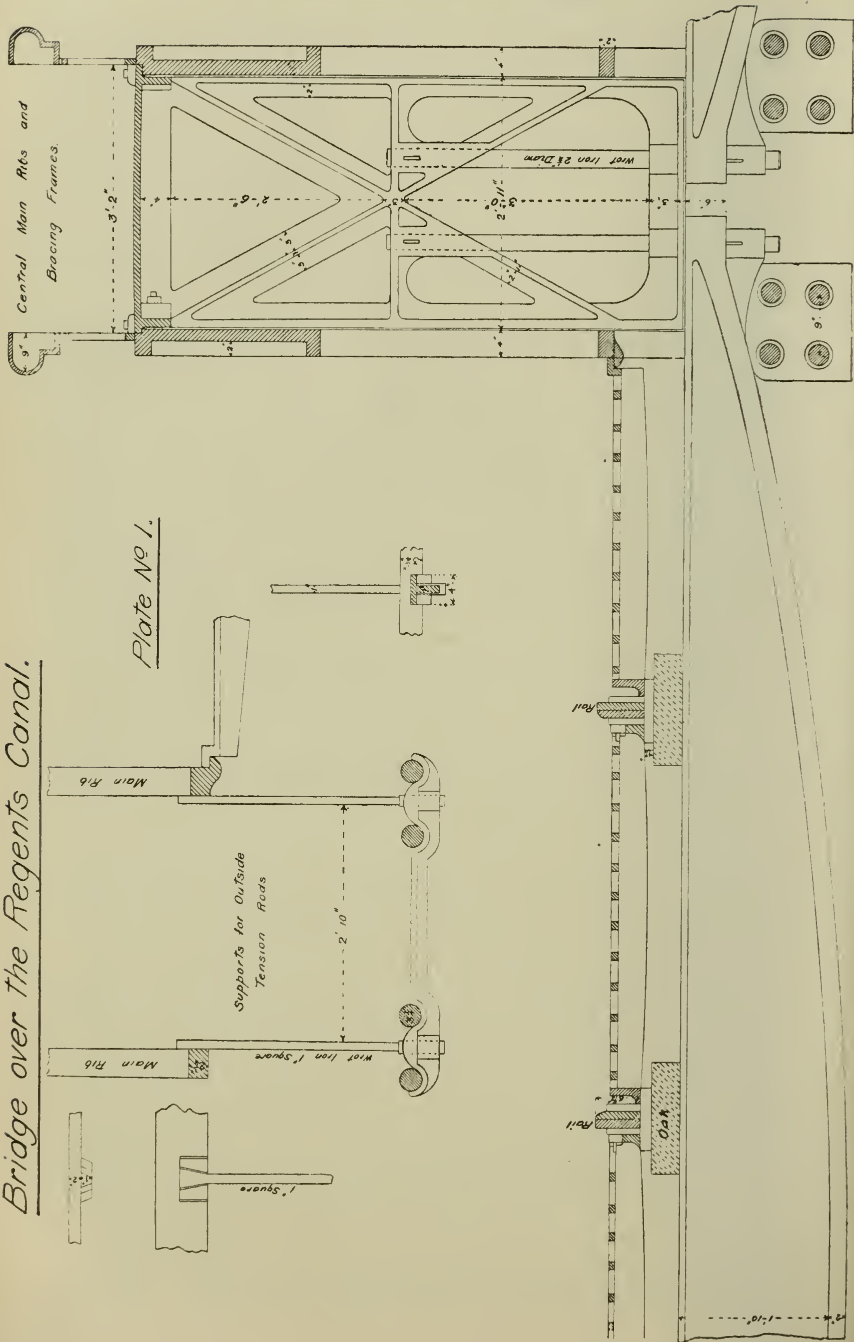
On the north side of this viaduct trouble was encountered in forming the embankment owing to the unstable character of the ground upon which it was tipped, the surface yielding before anything approaching the full height had been reached, necessitating great precautions being taken.

On the south side, however, the difficulties met were of far greater magnitude, and the completion of the work was delayed. When tipping operations first commenced during the winter months the material put into the bank consisted of gravel, sand and blue clay, which for a time stood well. Later on, as the excavation of the adjoining cutting proceeded, soapy clay was met with, which, when tipped on a turf bottom, led to the starting of perhaps the worst slip on the whole line, despite the fact that a good proportion of dry material had been mixed with the wet stuff. Efforts to complete the bank were entirely frustrated by continued slipping at the toe, which ran out nearly 150ft. on the adjoining land, and it was eventually decided to abandon work at the spot, a temporary timber bridge being constructed over the slip to enable the bank between it and the viaduct to be put in hand.

To avoid risk of trouble on this latter length, a trench 5ft. deep was first excavated for practically the full width of the embankment, the material taken out being used to form mounds along either side to weight the toe of the tipping.

The temporary bridge was removed the following summer and work recommenced on the slip, which still moved outwards and was not finally subjugated until sufficient stuff had first been deposited outside the slip to balance the weight of the bank. The difficulties met with at the Blisworth cutting have already been referred to, and it is only necessary to say that considerable lengths of retaining wall had to be built through the lower clay and shale, the upper beds of rock being underset to provide space for the walls, which were inverted to withstand side pressure. The limestone rock in this cutting was of an exceedingly close texture and had to be removed by blasting.

The course of the railway intersected the Grand Junction Canal at several points and the bridges designed by Robert


Bridge over the Regents Canal.
Plate No 1.
Central Main Ribs and Bracing Frames.
Wrot Iron 2¼" Diam
Supports for Outside Tension Rods
Main Rib
Main Rib
Wrot Iron 1" Square
1" Square
Rail
Rail
Oak
3' 2"
2' 10"

Stephenson for carrying the line over the same were generally of the arched rib type.

At the crossing near Boxmoor, the canal was intersected at an angle of 40 deg., rail level being 29ft. 8in. above the water line. The bridge consisted of six main ribs of cast iron, forming an arch of 66ft. span on the skew, the square span being 33ft. 6in., the ribs being 2ft. deep at the crown and 2ft. 9in. at springing. The arch had a rise of 11ft. 9in., each of the ribs being cast in three lengths, bolted together through flanges by bolts 2in. diameter. The thickness of metal was 2in. in the webs, and 6in. in the top and bottom mouldings.

The ribs were designed to spring from cast iron plates 2in. thick, cast in two pieces and bolted together with four 2in. bolts, the rib seat being recessed so as to present a face at right angles to the direction of the arch, the rib being keyed into place by wrought iron wedges. Sockets were cast on the sides of each rib to receive the ends of transverse and diagonal bracing pieces, the whole bridge being secured in position by wrought iron tie bolts. The four inner ribs acted as direct rail bearers, oak timbers running along their tops and being bolted down thereto by wrought iron bolts spaced 3ft. apart on alternate sides. The floor of the bridge consisted of cast iron plates over which gravel ballast was laid. The Weedon Viaduct contained five arches, each of 50ft. span and 35ft. in height.

At Buckby Wharf another fine bowstring bridge was constructed over the Grand Junction Canal, the span being 70ft.

The superstructure consisted of two main cast iron ribs on either side, strongly braced together laterally by cast iron frames from which suspension rods descended for the support of the cross girders. The main ribs were held longitudinally by wrought iron rods in a similar manner to that adopted at the bridge over the Regent's Canal.

The viaduct over the Avon was constructed with nine elliptical arches of 24ft. span, and that over Lawley Street and the River Rea, on the outskirts of Birmingham, had ten segmental arches, each of 50ft. span, the length of the viaduct being 710ft., and its cost £16,000.

The specification for the formation of the road bed and the laying of the permanent way was as follows :—

" The rails will be in lengths of from 12 to 18ft., and weigh 50 lb. per lineal yard. They will be supported every yard by a cast iron chair, or pedestal, which will weigh about 20 lb., and be accompanied by two wrought iron keys for fixing the rail in the chair, and two pins for fixing the chair upon the block or sleeper. The sleepers will be of wood; the dimensions of each part and the construction of the whole is shown upon the drawing. The Company will reserve to themselves the right of directing whether stone blocks or wood sleepers shall be used, or both,

and if both, in what proportion and situation. The material for ballasting shall be composed of broken stone or clean gravel, entirely free from any admixture of clay, capable of setting hard, and not retentive of moisture. If broken stone be used, none shall be larger than cubes of 2in. The ballasting shall be spread for the whole surface of the top of the embankment and bottoms of excavations, between the drains, and a uniform thickness of 10in. where stone blocks are employed, and 18in. where wood sleepers are used. This stratum of ballast shall be beaten into a firm and solid mass by heavy beaters, worked by at least two men, and the thickness before mentioned shall be considered to apply only after this operation has been effectually performed. Upon this surface the blocks and sleepers are to be laid in their proper situations for receiving the rails.

"When stone blocks are employed, each block shall be bedded in its proper situation, by frequently lifting it by a spring lever to the height of 1ft. above the surface and letting it fall forcibly on the ballasting; this operation shall be continued until no sensible difference of level is perceived after each fall. Should the block then be found too low, it shall be removed, and more material placed in its intended bed, and the same operation continued until the block has reached its proper level, and has obtained as firm and uniform a bed as can be obtained throughout the whole area of the under side of the block. When wooden sleepers are employed, the ballasting for the intended bed shall be beaten by heavy beaters, and each sleeper also forcibly beaten when it has been placed in its position, until it has been firmly and uniformly bedded throughout its whole length, and reached its proper level. If it be found lower than required, it shall be removed, and additional material placed under its bed; the same process as before must then be renewed until it has reached its proper level. The rails must be laid at their proper level, each of them parallel to each other, and at the same height at any point. The joinings must be made perfectly even, whether square, half-lapped, or scarfed, and be firmly secured in the chairs. The two lines of way to be 6ft. apart, and the width between the inside of the rails 4ft. 8½in.

"The stone blocks will be delivered to the contractor in a rough state, and he will be required to drill two cylindrical holes in each block, 6in. deep and 2¼in. in diameter; to make the upper surface of each block perfectly level; to drive the oak trenails and cut off their tops flush with the surface of the block; and to fix the chair firmly in its position by means of the iron pins furnished to him for that purpose. The wood sleepers will be delivered to the contractor as sawn out, and he will be required to make their upper surfaces perfectly level for the reception of the chair, which must be firmly fixed in the exact gauge. The pins shall not be driven into the sleepers without the holes having

been previously bored with a proper sized auger. The rails must be securely fixed into the chairs by means of two keys. The chairs shall be firmly fixed on the sleepers or blocks. The whole of the upper surfaces of the stone blocks must be worked to a plain surface, and a space in the centre of sufficient size for the whole bed of the chair must be fair tooled perfectly level, so that the chair will rest perfectly steady upon the block. Any of the rails which may be twisted or bent in the least degree to be made perfectly straight with proper hammers and anvils previous to their being laid down. Should any gravel or any other suitable material occur in any of the excavations included in this contract, the contractor shall be at liberty to use the same; but if in so doing he shall cause any deficiency in the material for the formation of the embankments he shall make up the deficiency by a side cutting in such of the excavations as the engineer may point out and at his own expense. If such side cutting shall require an additional quantity of land, the contractor shall indemnify the Company for the expense of purchasing the same."

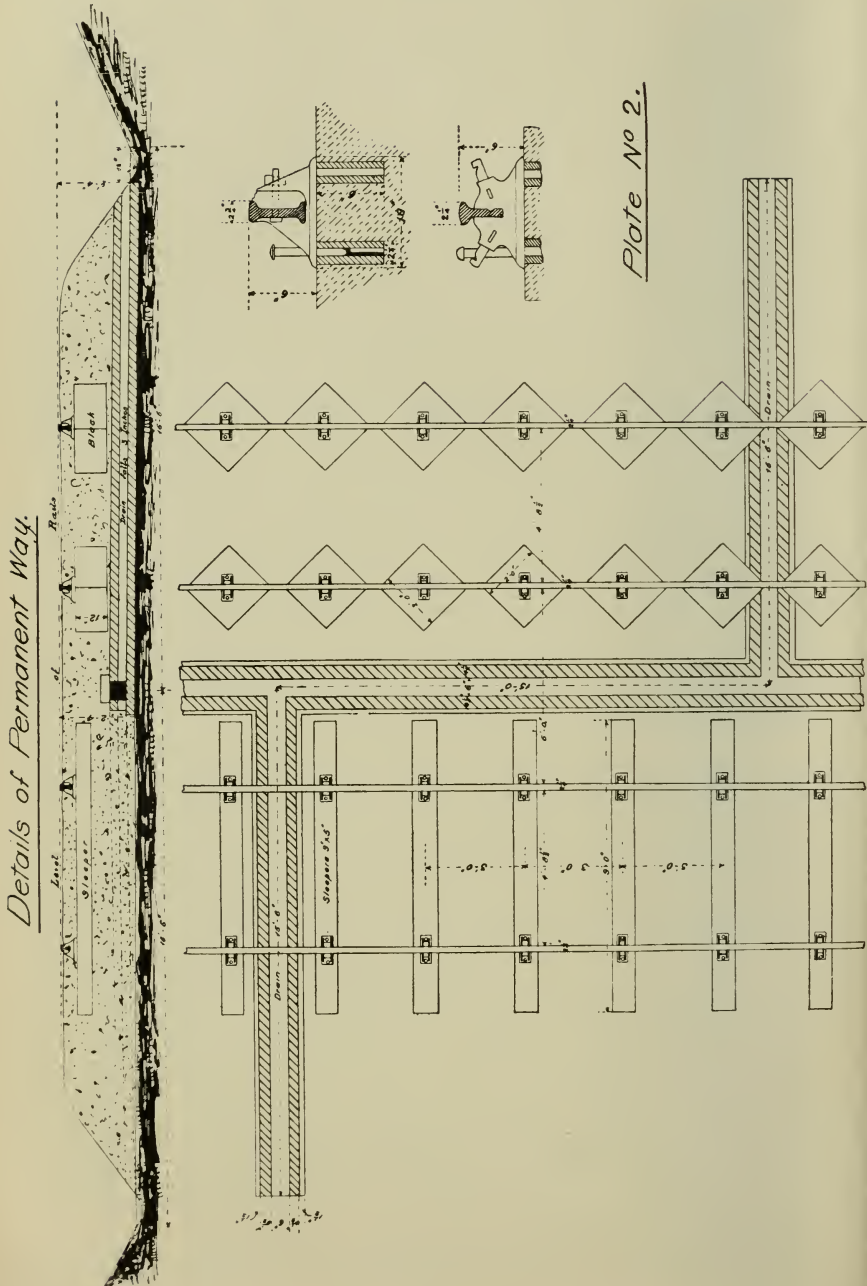
Details of the permanent way are shown on Plate 2.

The foregoing description of the railway has been built up on the information contained in the volumes published during the earlier years of railway construction, notably in those written by S. C. Breese, Thomas Roscoe, Peter Lecount and Francis Whishaw. Unfortunately, the particulars available are too limited to enable full justice to be done, and it is to be regretted that a more worthy account has not been preserved of this and other pioneer works.

The value of the retrospect lies in the fact that a comparison of the general planning of the London and Birmingham Railway with that of other railways of the same period brings out very strongly the inherent qualities of Robert Stephenson, both as a practical engineer who had implicit faith in the future of railways, and also as a man of the highest integrity, who gave only of his best, and steadily refused to depart in any way from the high standard which he set himself to carry out.

To plan and construct such a railway at the present date, when the earlier deep-rooted prejudice against such schemes has been almost entirely removed, and with the assistance of all the benefits that the advance of science bestows, would be no light task, and with these points in view the ultimate success obtained can perhaps be better realised. As Francis Whishaw remarked in 1842, "It must ever be remembered that Mr. Stephenson's grand object was to make this railway as mechanically perfect as possible, or, in other words, to reduce the gradients to the minimum consistent with the natural difficulties to be encountered throughout."

The finished cost of the London and Birmingham line approached £50,000 per mile, while that of the Grand Junction


Details of Permanent Way.
Plate No 2.
Block
Rails
Level
Sleeper
Drain
Sleepers 9"x5"

Railway, which formed its first immediate connecting link with the North, was probably less than half that sum. The gradients of the latter line, however, were as steep as 1 in 85, while on the former (excluding the Euston extension) Stephenson adopted a maximum rise of 16ft. per mile, or 1 in 330, thereby refusing to sacrifice future working efficiency for economy in the first cost of construction.

As Dr. Smiles relates in his "Lives of the Engineers," "Robert Stephenson once stated before a Parliamentary Committee that every successive improvement in the locomotive was being rendered virtually nugatory by the difficult and almost impracticable gradients proposed on many of the new lines."

That this latter view of the question was not altogether accepted at the time is shown by the following extract from Whishaw's "Railways":—"It is clearly more advantageous, in most cases, to graduate a line so as to render the works as light as possible, and thus cause the original outlay to be comparatively small, than to effect a complete system of gradients for the purpose of reducing the annual expenditure; it must ever be borne in mind that this addition to the original outlay also requires an annual charge in the shape of interest. These lines (*i.e.*, the London and Birmingham and the Grand Junction) serve well to illustrate the two systems, and the results of future years' experience will throw much light on this branch of railway engineering, which is, at present, but in a comparatively infant state."

That the foresight and sound commercial instincts which Robert Stephenson happily combined with his high engineering skill were correct is amply borne out by the successful working of the London and Birmingham Railway to-day.

He may have planned still greater works during the succeeding years of his career, and although the individual identity of his pioneer work may now be largely merged in the great railway of which it now forms part, yet we cannot pass the silent statue in the booking office at Euston Station without remembering the value of that work, and reflecting on the high ideals formed and steadfastly maintained by its designer and constructor.

GENERAL RESULTS OF TRAFFIC FOR ONE YEAR.

(Extracted from the Minutes of Evidence given before the Committee of the Lords, 1832.)

Means of Transit.	Number of Journeys of 110 miles.	No. in each.	Total carried.	Expense by the present means.			Expense by the Railway $112\frac{1}{2}$ miles.	Time. At present.	Time. By the Railway.
			Passengers.	£	s.	£	Passengers at 2d. per mile each £	Hours.	Hours.
Four-horse Coaches counted on the road	21,641	9	194,769	316,499	6				
Two-horse do. do. ...	4,221	6	25,326	44,003	9				
Pairs of Post Horses do. ...	7,622	3	22,866	83,942	0				
Commercial Gigs do. ...	5,569	1	5,569	11,138	0				
						455,483	227,819		
Contingent Coaches from Stamp Office Returns	23,745	9	213,705	347,270	6				
Proportionate Number of Pairs of Post Horses	6,998	3	20,994	76,978	0			$12\frac{1}{2}$	$5\frac{1}{2}$
Ditto of Commercial Gigs ...	5,113	1	5,113	10,226	0				
						434,474	219,827		
		Cwt.	Tons.						
Private and Stage Vans counted on the road	1,600	{18} {30}	$2,315\frac{1}{4}$	18,522	0			30	—
Stage Waggons do. ...	3,665	70	$12,827\frac{1}{2}$	76,965	0			60	—
Errand Carts do. ...	11,543	10	$5,771\frac{1}{2}$	34,629	0			40	—
						130,116	58,821		
		Tons.							
Boats counted on the canals ...	11,131 (149 miles)	11	122,428	—		506,070	286,940	72	—
						£1,526,143	£793,407		

VISIT TO SWANSCOMBE CEMENT WORKS.

The third vacation visit of the present session took place on Friday, July 7th, 1911, when, by kind permission of the Associated Portland Cement Manufacturers (1900), Ltd., a number of members of the Society and their friends visited the Swanscombe Northfleet Cement Works. It was at Northfleet that the earliest cement works were erected by the younger Aspdin, whose father had invented the product in 1824, and subsequently other works were erected by firms whose names have since become world-famous. The majority of these firms were combined in one company in 1900.

The district in which these works are situated is peculiarly adapted to be the centre of the cement industry on account of the presence of unlimited supplies of chalk and clay, an ample quantity of fuel, and ready access to all parts of the world through the Port of London.

The visitors were shown the chalk quarries adjoining the works, and the clay brought from the Medway. The amalgamation of chalk and clay in definite proportion is effected by batteries of washmills, the resulting slurry passing through a screening mill in a finely divided state. The slurry then passes into the large mixing and storage tanks, and is finally pumped into rotary kilns, in which the contained water is evaporated, and the dry material thus obtained is heated up to a temperature of about 2,800 deg. Fahr.

The hot clinker then passes through rotary coolers, which extract the heat, and from thence is delivered to the grinding mills, in which the clinker is reduced to a very fine powder. During the final stage of the grinding process steam is injected into the mill, subjecting each particle of cement to a repeated process of superficial hydration, thus regulating the setting time, and turning out the cement in a condition for immediate use, thereby obviating the trouble of turning over the cement before use on the site of works.

The visitors were shown the cooperages, where casks for packing cement for export are made by machinery, many of the machines being of a special character, and patented by the Company.

Tea was provided by the Company for their guests at the conclusion of the visit, after which a vote of thanks to the Company for their courtesy was proposed and heartily accorded.

THE COLONIES AS A FIELD FOR ENGINEERING WORK.

By H. Conradi.

An important problem which, in the interests of the industrial, commercial, and trading classes, demands prompt solution, is that of securing permanent employment for workers of all grades. The demand for workers is now very fully satisfied in this country with its millions of population, and it is only comparatively rarely that fresh work, offering more or less permanent employment, is undertaken in any industry or commercial occupation.

The problem of unemployment has become very acute here, but looking abroad it will be seen that in the British Colonies enormous territories are lying uncultivated. The Governments of these Colonies are asking for hands to develop them, and are offering assistance to British workers and their families who are disposed to settle in these new countries, where there is work awaiting them, sufficient not only for the present time, but for generations to come. All the British overseas dominions have established offices here, each with a resident staff, to demonstrate the rich products of their countries and to give information to intending emigrants.

An enormous amount of all kinds of industrial, engineering and commercial work is required to be done in the Colonies; in confirmation of which statement the author would quote from an excellent paper read before the Royal Society of Arts (February, 1910) by the distinguished engineer and geographer Mr. C. Reginald Enock, F.R.G.S., who has visited the Colonies. He states as follows :—" In the oversea territories we have boundless plains of wheat-growing and cattle-raising capacity, endless mountain ranges, full of iron, gold, coal, and all other minerals, limitless forests of valuable timber, rivers and seas teeming with fishes, lands uncultivated, forests uncut, mines unworked, railways and roads unbuilt, and tenantless town sites extending over continents." Similar views have been expressed by the Congress of the Chambers of Commerce, held at Sydney (September, 1909), and by Lord Strathcona, Governor-General of Canada.

The author's solution of the unemployment problem would therefore consist in the establishment of a State-aided Emigration and Colonisation Department, assisted by private enterprise. This organisation would direct its efforts towards facilitating

emigration from our populous centres into the remaining uncultivated districts of the $11\frac{1}{2}$ millions of square miles comprised within the British Empire. The statistics given in this paper afford some idea of the immense resources of our Empire.

The Empire of India is a most important country of about 1,572,624 square miles, with a population of over 300 millions. Its engineering activity is shown by the fact that up to March, 1901, approximately 13,670 miles of railway of standard broad gauge (5ft. 6in.), 9,424 miles of metre gauge (3ft. 3in. to 3ft. 6in.), and about 600 miles of private and special gauge lines had been constructed and worked, while at the same time over 3,000 miles of new lines were authorised and in the contractor's hands.

A large amount of important engineering work is carried out by the Indian Government through their Public Works Department, but it would lengthen this paper too much to enter into further details of constructive engineering work such as canals, irrigation works, bridges, and so on, or to give particulars of other industries, such as agriculture, tea, coffee, indigo, and tobacco planting, weaving, carpet making, etc. After agriculture the most important industry in India is the weaving and spinning of cotton. There is no extra demand for British industrial workers generally, except in special cases and higher grade positions. The coal production is over five million tons per annum.

The Dominion of Canada contains the provinces of Quebec, Ontario, Nova Scotia, New Brunswick, Prince Edward Island, Manitoba, Alberta, Saskatchewan, and British Columbia, besides the North-West Territories. The land area of the whole Dominion, exclusive of the northern Franklin Island of 590,000 square miles, contains 3,619,819 square miles, with a watershed of 125,755 square miles, or a total of 3,745,574 square miles. In 1901 there were about 100,000 square miles occupied, and deducting this from the total area there remain some $3\frac{1}{2}$ million square miles still uncultivated, to be given over to agriculture, forestry, mining, engineering, building, and manufacturing trades generally. The population is only $5\frac{1}{2}$ to 6 millions, agriculture being at present the chief industry.

The total export of agricultural produce alone amounted in the year 1900 to about \$78,800,000 (£15,760,000) The exports are principally the products of the mines, the forests, the sea and rivers, and the farms, and amounted in 1900 to the value of £6,500,000. The principal imports are cotton and woollen goods, flax, hemp, and jute, leather, oil, paper, and silk, besides iron and steel.

The minerals comprise gold, silver, copper, iron ore, coal, lead, platinum, nickel, antimony, amounting in 1898 to over $4\frac{1}{2}$ millions sterling. Very extensive coalfields have been opened up by the Canadian Pacific Railway. The construction of the

railways generally has greatly assisted trade by opening up new sources of supply, and, as will be shown later, there is still plenty of scope for very large developments.

The chief seaports from east to west are Halifax, St. John, Quebec, and Montreal on the Atlantic coast, while Vancouver, Esquimault, and Victoria are situated on the Pacific coast. There are four graving docks in Canada: At Esquimault, 430ft. long by 90ft. in width; Quebec, 445ft. by 100ft. wide; Halifax, 585ft. long by 102ft.; and Kingston, 280ft. by 79ft. There are along the coasts over 1,500 lighthouses and light stations, foghorns, and so on. Inland communication is by means of railways and canals. There are in all 166 railways, the amalgamation of 25 of these lines forming the Grand Trunk Railway; while 23 others compose the system of the Canadian Pacific Railway. Besides these two great systems there are the railways operated by the Government under the name of the Intercolonial States Railways.

The Grand Trunk Railway, established in the developed portion of Eastern Canada, connecting all the cities and nearly all the towns in these provinces, has a total length of 6,700 miles. The Canadian Pacific Railway, running from St. John to Montreal and from there across the continent to Vancouver, is 9,286 miles in length. The Canadian Northern Railway system in Central Canada has a length of 4,000 miles. The Intercolonial States Railway, connecting Montreal, the commercial metropolis, with the ports of Halifax and Sydney in the maritime provinces, having a total length of 1,496 miles. The Great Northern Railway of 3,400 miles is, however, a United States concern.

Besides these railways of nearly 22,000 miles in length there are also the rivers and canals. The great lakes and the St. Lawrence river are the route of the main grain trade of the West to the principal seaports. The timber, log, and lumber trade of Ottawa, the lower St. Lawrence, and New Brunswick is carried by water, and for these two trades the canals are the necessary carriers. The tonnage in 1897 was over 8½ millions. In combination with the railways is the important postal and telegraph work. In the year 1898, when a record was taken, the post forwarded nearly 135 million letters, over 28 million postcards, over 5 million books and circulars, over 26½ million newspapers, and nearly 350,000 parcels.

The telegraph lines are principally owned and worked by public companies, while the Government owns and operates about 2,751 miles of land wire and about 239 miles of cable, which combined carry about 42,550 messages yearly. The bulk of the telegraph business is done by the Canadian Pacific Railway, operating 8,385 miles of wire, carrying 1,650,000 messages in 1898; by the Great North-Western Railway Co., operating 18,228 miles, carrying 2,400,185 messages; and the Western

Union Co. (chiefly in the maritime provinces), working 2,935 miles, carrying 357,080 messages. The total being about 29,550 miles and 4,407,265 messages. The telephone is in use throughout the settled parts.

The following facts show that there is still in Canada plenty of scope for the development of railways involving the general development of the adjacent country. The Grand Trunk Railway Co. of Canada made application, on the 6th April, 1910, for capital for the construction of branch railway lines as feeders for their main lines in the province of Saskatchewan to the extent of 475 miles.

Still more important is the announcement of the work to be undertaken now by the Grand Trunk Pacific Railway, the chairman of which stated, at the company's half-yearly meeting, on the 14th April, 1910, that the Government of Canada and the Grand Trunk Railway were engaged upon the greatest undertaking in course of construction in the world, with the exception of the Panama Canal. The Government undertook to build the line from Moneton in New Brunswick (where it would connect by the Intercolonial Railway with the ports of Halifax and St. John) to Winnipeg, some 1,800 miles. The Pacific Company undertook to build a branch line from Fort William on Lake Superior for a distance of about 200 miles to Lake Superior Junction on the National Transcontinental Railway (about 245 miles east of Winnipeg), thus connecting the great lakes with Winnipeg. This branch was known as the Lake Superior branch. The Pacific Company also undertook to construct the line from Winnipeg to the Pacific coast, a distance of 1,753 miles. The total length of new lines at present projected is therefore 3,750 miles.

With the help of an Emigration and Colonisation Department, suitably organised and efficiently worked, many of those who have difficulty in making a living for themselves in this country should be able to find a suitable field for their activity, and one which would benefit both themselves and their children. A further glance at the other Canadian provinces will show where, besides agriculture, other and diverse industries have started developing. The provinces of Newfoundland, Prince Edward Island, Nova Scotia, and New Brunswick are, as yet, principally engaged in agriculture; but in all of them, with the exception of Prince Edward Island, coal, iron, and gold production are going on. For example, the industrial production of Nova Scotia in 1909 amounted in value to $109,250,000, equivalent to about £22,500,000.

The Province of Quebec contains about 233,000 square miles, with a population of nearly 2,000,000. Iron is obtained and used in the blast furnaces at Radnor and Drummondville. Over 10,000 tons of pig iron were produced in 1907, and 29,600 tons of

copper were manufactured. Over 2,000 miners are employed. There are big forests and a large timber trade is maintained.

The Province of Ontario, of about the same area, possesses manufactories of agricultural implements, machinery, hardware, furniture, and woollen wares, as well as large ironworks, shipbuilding yards, cement works, and stone quarries. It has a comparatively large production of silver, iron, copper, and nickel, some production of gold, and a large timber trade.

The Provinces of Manitoba, Saskatchewan, and Alberta are at present mostly farming countries, but as the great railway companies of Canada had in 1908 about 3,250 miles of railway under operation in the province of Saskatchewan alone, and great extensions in all these provinces under construction, the establishment of large manufacturing concerns in all industrial and engineering branches was expected.

The Province of British Columbia relies chiefly on its mineral wealth. The production of minerals in 1908 was of an estimated value of nearly £5,000,000. The province has also over 2,600,000 square miles of forests, besides rich agricultural and fruit lands. Less than one-tenth of the available land is settled upon, and much less cultivated. There are about 1,600 miles of railways in the province at present, with extensions contemplated by the Canadian Pacific Railway Company. In closing these notes of the resources of Canada in respect of engineering work it may be mentioned that engineers qualified to practise in the United Kingdom may do so in Canada, their success depending largely on their own ability and professional standing, but in the provinces of Quebec and Manitoba no one may practice as a civil engineer unless he is a member of the Canadian Society of Civil Engineers or holds some equivalent qualification. As to the professional appointments in the Civil Service, persons born and trained in Canada naturally have the preference, but openings occur in newly settled districts, with good prospects of employment.

The Commonwealth of Australia.—Sir George Reid, the High Commissioner for Australia, speaking at the Royal Colonial Institute, on the 16th March, 1910, alluded to the great industrial and commercial advance of this colony. Already Australia has a trade of nearly £200,000,000 a year. The shipping which enters its ports amounts to 19 million tons a year, and they are able to point to manufacturing industries employing 257,000 hands, the plant and buildings representing 53 millions of capital. To assist in promoting the industrial and commercial unity of the Empire Australia is going to spend not less than £3,500,000 in the provision of ships for His Majesty's Navy, with a contribution to their upkeep of £750,000 per annum. The area of Australia is about

1,885,882,240 acres, of which the State has sold nearly 107 million, and holds under lease 779 million acres, leaving nearly 1,000,000,000 acres of uncultivated land to be developed. The five provinces have abundance of gold, copper, iron, coal, silver, lead, and tin. The value of gold obtained from the commencement of mining in 1851 to the close of the year 1907 amounted to £488,428,157.

Nearly the whole of the railway lines of Australia are the property of the State Governments. At the end of 1907 there were over 14,000 miles of railways open for traffic, the cost of their construction and maintenance having been £137,000,000. The length of telegraph lines in use is about 42,200 miles. Telegraphic messages sent in the year 1899 were about 7,745,000. The working expenses in the whole of Australia for railways in the year 1900 were about £6,397,686; for postal and telegraph about £2,095,810.

In the state of Victoria there is no legal restriction on practising as a mechanical, electrical or civil engineer, except in regard to bridge work and roads built out of local rates subsidised by Government, the engineers in such cases being obliged by law to pass a qualifying examination. Certificates of qualification are granted to corporate members of recognised engineering institutions of the United Kingdom and Australia.

New South Wales possesses extensive seams of coal, the coal-producing area being estimated at 24,000 square miles. Gold, silver, zinc, tin, copper, and iron are also worked. The aggregate value of all the minerals mined in 1907 was £10,577,378. Over 17,000 miners are employed at the different mines. The area of the State is 310,700 square miles. The production of wool is a most important industry. Nearly all the railways are Government lines; 3,600 miles of railway were open in 1908, employing 18,000 persons. The country is rich in hard timbers for bridge work, piers, railway sleepers, etc., as well as woods such as cedar, rosewood, etc. There is a fair chance for skilled mechanics, ironworkers, masons, bricklayers and carpenters to obtain work. Mining engineers must hold a certificate of competency obtained by examination. Experienced hydraulic engineers will find fair openings. The Government Civil Service includes a Public Works Department, entrance to which is by examination between the ages of 16 and 21.

Southern Australia.—Its area is 903,690 square miles, and is at present mostly an agricultural country. There are about 2,000 miles of railway open. The principal works there are for the manufacture of agricultural implements and machinery for brickmaking, sawmills, &c. There are also shipbuilding yards at Port Adelaide, and Government railway works at Islington near Port Adelaide. There is no restriction on practising as an engineer.

Queensland.—The area is 668,500 square miles. The principal industries are agriculture and mining. The minerals worked are gold, silver, copper, tin, and coal. The gold mining industry in 1907 employed 14,000 miners. The total number of miles of railway open to the end of 1907 was 3,200 miles. There are no restrictions, no licences, no examinations imposed to practise professionally as an engineer. It is officially stated that well qualified engineers have excellent prospects for work there.

Western Australia.—The area is about 975,920 square miles. Agriculture and forestry are up to now the principal industries. The State railways opened up to 1908 were about 2,000 miles. As to minerals, gold is one of the most important products, giving employment to about 16,000 miners. The total output from 1886 to 1908 amounted to 2,004,697 fine ozs., valued at £85,004,286. The country is celebrated for its timber, especially jarrah and karri. About 14,000 workers are employed in other industries. There is no special qualification required for those desiring to practise as engineers.

Tasmania.—In a paper read before the Royal Colonial Institute, on the 16th November, 1909, by the Hon. John McCall, M.D., Agent-General, and Lieut.-General Sir Edward Hutton, it was stated that this colony has the finest climate, abundance of water, beautiful hills, valleys and surroundings, and in its industrial and economical aspect the least fluctuations of commercial excitement. It is seldom difficult for anyone to find work of some kind or other, though at times he may have to shift his quarters to obtain it. The necessaries of life are cheap, wages are high, and a man with family will often have a much better chance of placing his children out well than he would have here. The foremost is the woollen, the next the timber industry; but there are also minerals in abundance. The minerals raised during the year 1907 amounted to a total value of £2,272,721. The great value of the timber may be shown by the fact that the contractor for the Dover Harbour works sent an expert a distance of 14,000 miles to purchase the timber there. The tin produced from the Mount Bishoff Mine approximates to the value of £4,500,000, of which £2,124,000 has been paid in dividends to the shareholders. Ironstone has been found by piercing the hill by a 260ft. drive, and fully 40,000,000 cubic yards of ore have been revealed. Engineers who have qualified in the United Kingdom require no other qualification, British diplomas and certificates being recognised. Mining engineers should find ready employment.

New Zealand.—This is an agricultural and pastoral country. The main export is wool, but minerals, timber, and coal are found in abundance. In 1908 there were open about 2,474 miles of Government railways, and 84 miles of private lines. Over

70% of the total trade is with the United Kingdom. "Workers experienced in mining for coal, gold, and other minerals," it is stated, have a good chance of obtaining work ; there is, further, a demand for good hard-working men and boys for all kinds of agricultural work." There is no restriction on practising as an engineer, no licence required, no examination, but there are few openings for professional men.

In a lecture held here Mr. R. W. R. Mulloy, of Canada, gave the following interesting data :—He stated the main difficulty of an industrial commercial nation was to find markets. New Zealand bought from England at the rate of £7 per head ; Australia bought from England at the rate of £4 per head ; Canada at the rate of £2 per head, and nearly 100% were finished manufactures. Every 100,000 emigrants they sent meant £200,000 more in British manufactures. The country consists of the North Island, of an area of 44,468 square miles, and the South Island, of an area of 58,525 square miles.

The South African Colonies.—A glance at the conditions of these countries, consisting of Cape Colony, the Transvaal, and the Orange River Colony, will at once show what industrial engineering work is going on there, and what development will be required. There are also other large territories which have not yet joined the Union, but are expected to do so later on. The most important of these is Rhodesia, the others being Basutoland, Swaziland, and Bechuanaland Protectorate. Their areas and populations are, in round figures, as follows :—

Territories within the Union.

	Area in square miles.	Population.
Cape Colony	277,000	2,409,800
Transvaal	119,000	1,269,950
Orange River Colony	50,000	387,320
Natal	35,370	1,108,750
Total	481,370	5,175,820

Territories outside the Union.

	Area in square miles.	Population.
Rhodesia	439,580	1,554,290
Bechuanaland Protectorate ..	275,000	129,920
Basutoland	10,290	348,700
Swaziland	6,540	85,490
Total	731,410	2,118,400

Ports of the United South African Colonies.

Table Bay Harbour.—Working capacity 8,000 tons per day. The storage capacity is 60,000 to 70,000 tons of cargo and 32,000 tons of coal. The harbour is sheltered by a breakwater 3,640ft. long.

Port Elizabeth Harbour.—Working capacity per day 5,000 tons.

Port of East London.—Tonnage handled in 1908, over 330,000.

Port Natal.—Storage capacity, 100,000 tons ; cost of equipment, £4,000,000.

Floating Dock and Workshop.—It is 475ft. long by 70ft. wide, and takes vessels of 8,500 tons of dead weight.

Colony of Rhodesia.—This colony possesses a railway system of 2,000 miles in length, connecting all the chief towns with each other and with the rest of South Africa. Of the direct Cape to Cairo transcontinental railway, no less than 1,373 miles lie in Rhodesia, being operated by the Rhodesia Railway Co., Ltd., and by the Mashonaland Railway Co. The late Cecil Rhodes, in 1889, extended the Cape Government railway from Kimberley to Vryburg in Bechuanaland, 127 miles north of Kimberley, which took about one year to construct at a cost of a little more than £4,500 per mile.

Comparative Statistics.

The total area of the British Empire is, in round figures, 11,200,000 square mlles, while that of Great Britain is only 121,340 square miles. A coal and iron-producing country with an area of only about 120,000 square miles could not hope to remain always supreme in its production against other countries with areas of 200,000 and 300,000 square miles. While other countries of greater productive areas must gradually go ahead, the production of Great Britain has always been particularly uniform and substantial.

In a lecture given at the Royal Society of Arts on the " Commercial Expansion within the Empire," by Mr. J. P. Hannon, late Director of Agriculture Co-operation in Cape Colony, it is stated that the statistics relating to the growth of British commerce during the past century are not, on the whole, satisfactory. From the official reports and the figures in the Board of Trade reports, statistics of the expansion of the import and export trade of the United Kingdom to foreign countries and British possessions have been compiled from the year 1854 to 1908. Taking the imports of merchandise into the United Kingdom from foreign countries and from the British possessions, they amounted, from foreign countries into the United Kingdom in the year 1908 to £463,125,000, and from the British possessions in the same year into the United Kingdom to £129,828,000, making a total of £592,953,000.

The exports in the same year from the United Kingdom to foreign countries were £251,349,000, and to the British possessions £125,754,000, making a total of £377,103,000; while it is further indicated that the total foreign trade of the British Empire in the same year of 1908 amounted to £1,120,815,000, the total inter-Imperial trade to £377,213,000, giving a total trade amount of the British Empire for the year 1908 of £1,498,028,000.

The lecturer concludes that it is every British subject's duty to assist in the development of the commerce of our country and the colonies and dependencies within the Empire itself, and that it must be supported by a policy of closer union on the part of all the states and peoples under the Crown, embodying at once preferential trade, transit facilities, and minimum rates for transport.

From more recent returns of the Blue Books of the Board of Trade for the British Empire, as the 47th Annual Abstract of the trade with the United Kingdom, the following data are given:—According to the latest returns the total area of the Empire is now 11,199,000 square miles, and the population, according to the census of 1901, is 343,748,000.

Postal Work.—The work of the Colonial postal department has enormously increased in recent years. During the year 1909 the 18,399 post offices in India dealt with 767,922,728 letters and cards; 101,192,285 newspapers, book packets, and circulars; 6,140,819 parcels; and 13,244,097 telegrams. Australia dealt with: letters, 372,501,343; newspapers, etc., 201,839,837; parcels, 2,917,464; telegrams, 13,890,277. Canada dealt with: Letters, 479,670,000; newspapers, 85,940,800. The Canadian figures have more than doubled in nine years.

It is interesting to compare the postal work of the Colonial postal department with that done in the new General Post Office in London (designed by Sir Henry Tanner) in order to show what an enormous amount of work lies before engineers in the development of any industrial branch in the undeveloped parts of the oversea British dominions, and even of foreign countries where English capital is invested and English engineers may be wanted.

The following statistics are taken from an extract of Sir Henry Tanner's paper read before the Royal Institute of British Architects, on January 2nd, 1911. The magnitude of the work is shown by the fact that at the date of the removal to the new General Post Office, known as King Edward's Buildings, there were 3,750 men of all ranks at work, inclusive of 1,400 postmen. In the meantime the force at the old Post Office buildings at Mount Pleasant had increased from 2,850 to 4,500 men, exclusive of the temporary force employed at Christmas. The work dealt with weekly was 5½ millions of letters, etc., delivered in the E.C. district; 3½ millions to other districts of London and by certain provincial mails; and 3½ millions despatched to the Dominions

and foreign countries ; in all $12\frac{1}{2}$ millions, or about 650 millions per annum. In consequence of the immense growth of the work the old building (designed by Sir Robert Smirke in 1829), which was sufficient to accommodate all branches, had to be abandoned, and seven large buildings provided to meet present-day requirements, yet the construction of an eighth building was under consideration.

During this period of 81 years the staff had grown from 800 to 20,000. The cost of the latest new building was £295,000. The increase of postal work during Christmas time in the new King Edward's Post Office building has been very heavy. At ordinary times about $8\frac{1}{4}$ millions of letters, postcards and newspapers are delivered in the City of London every week. It is estimated that this year's collection and deliveries during that period exceeded by more than two millions the average weekly figures. The amount of circulars sent out came to nearly 1,000,000. The foreign mail department despatched 103,900 bags containing 29,500,000 letters, postcards and newspapers, an increase of nearly 2,000,000 compared with the amount during Christmas week, 1909.

8,900 bags were despatched to the Colonies containing 3,217,000 letters distributed as follows :—Australia 749,000 letters, etc. ; India, China, and Ceylon, 862,000 ; South Africa, 509,000 ; Canada, 559,000 ; and the United States, 531,000. For the whole of London the postal staff had to be increased temporarily by 8,500 workers, 500 more than last year. The Post Office arrangement worked most successfully. According to the Postmaster-General's report of 31st March, 1910, the number of postal packets delivered in the United Kingdom, however, during the year amounted to a total of 5,105,890,000, as follows :— Letters, 2,947,100,000 ; postcards, 866,800,000 ; halfpenny packets, 974,200,000 ; newspapers, 199,600,000 ; and parcels, including those sent from this country to places abroad, 118,190,000. During the year 1910 the Post Office dealt with 86,884,000 telegrams.

It is estimated that during the year 4,926,000 messages were sent on the telephone for transmission as telegrams, and 163,400 for transmission as express letters. By the Marconi Co.'s system were sent during the year 1909-10 outward : Radio-telegrams to ships, 3,266, and inward : Radio-telegrams from ships, 27,727.

The statistics enumerated here and the particular details given will permit a fair comparison of the productive capacity of the United Kingdom with the productive capacity actually developed and capable of immense extension of the British dominions over the sea, and consequently enable every practical and experienced engineer to draw his own conclusions as to the immensity of work waiting to be carried out by engineers in all

branches of the profession, thus being able to give full and uninterrupted employment to all its industrial workers, not only for the present but for generations to come. Considering the millions of square miles of country to be worked and made productive, with all the industrial branches to be established consequently following in its train, starting from the building of the huts of the first settlers to the formation of the village, then to its transformation into a town with the necessary establishment of engineering branches and industries corresponding to the requirements of a town; considering, further, its development and extension, with factories, workshops, and industrial establishments of all kinds. These statistics will show the utmost necessity of establishing Colonisation Departments all over the United Kingdom in connection with all its colonies, such Departments to be financially assisted by the Home Government, by those of these Colonies, and by private companies, for the maintenance of our engineering industries, our commerce, and for the benefit of our industrial classes.

The particulars contained herein were obtained from the offices of the High Commissioners and Agents of the Colonies established here, the Government Emigration Office, the Imperial Institute, and from the public Press.

SOME NOTES ON DRAWING OFFICE ORGANISATION.

By Frank G. Woollard [Member].

The author intended at the outset to make this paper a complete record of his views on drawing office organisation, but he has to confess that, with the time at his disposal, this has been impossible. He is therefore obliged to offer the paper in the form of a series of somewhat disconnected notes on the subject.

This may serve a useful personal purpose, as it will enable him to embody the broader opinions of others before making even a relatively settled programme for his own guidance. It was intended also that this review should embrace the needs, in outline, of the many types of drawing offices existent, but it has been found more convenient for the purpose of this paper, to treat of the engineering factory as, probably, the most complex of all drawing office problems, and here it is, with reluctance, that the author feels compelled at present to leave this fascinating subject.

Material.

A sketch dealing with the history and growth of the drawing office as a department is not within the scope of this paper. Yet it is interesting to note that this now all-important branch of a modern engineering business was vested, in earlier days, entirely in the person of the proprietor of the business, but with the growth of industrialism, and the consequent greater area covered by mechanical and engineering activity, the elemental sketch, made perhaps with a stick upon the floor of the foundry or chalked upon the wall, has vanished as completely as the Maudslay models beaten from lead bar, as completely as has vanished the master's individual supervision of the man. True it is that there were drawings in those earlier days, but these were for the most part made by the master, were made sparingly, and were mostly in the form of general arrangement plans. Drawings of details are a comparatively modern innovation, and the "one job one sheet" style of the modern factory entirely so. The advent of the limited company has also to a great extent restricted the influence of the "master" in design work, hence instead of the one-man control of earlier days we have that exceedingly complex and somewhat impersonal department—the modern drawing office.

The drawing office is now the centre of the nervous system of a factory or works, and in consequence it is most essential that it should be in tune with all the other departments in the system,

(the term "works" being employed to denote operations conducted from a distance, in contra-distinction to a factory, where the drawing office is on the spot). The influence of the drawing office is so far-reaching that, to push the analogy to its utmost limits, any derangement of that centre is liable to be made manifest at unexpected times, in unsuspected places, quite possibly far removed from the original source of the disturbance; and faults made at headquarters cause some very unpleasant moments when it becomes necessary to diagnose the cause of trouble that may be set up. As already remarked, the modern drawing office as a department is somewhat impersonal, and the foremost object in the organisation of a drawing office must be the very full consideration of methods by which the drawing office may be knitted to all those departments that are dependent on or allied to it. One of the worst features of modern specialisation is the tendency to form a series of watertight compartments throughout the body corporate of the factory, and with these facts in mind (but also remembering that it certainly is not the business of the man systematising the drawing office to upset all the other departments in that process), we can proceed to analyse the functions of the drawing office, and to consider the most desirable means of accomplishing the tasks which are embodied in those functions.

Briefly stated, the drawing office staff of to-day may be expected to draw up specifications and forms of estimates (possibly including prices), to make the essential inquiries and calculations on the receipt of an order, to lay out the necessary general arrangements, to order patterns, materials, and special tools required, and to supply the factory with very explicit diagrams and instructions for every item that goes to complete the order. Further to this is the duty of noting for future information any difficulties that may have occurred in the execution of those instructions, and to watch opportunities for cheapening production. Some firms extend this capacity, some lessen it, by permitting other departments to help with these functions. In any case the drawing office will be the court of appeal on all matters appertaining to technical branches of the work.

Furniture is a very large factor in organisation. It is not suggested that an elaborate office, bristling with the latest improvements, will run by itself, but all system is based primarily on the very old adage: "A place for everything and everything in its place"; this is the foundation of all organisation; proper accommodation must be provided.

As to the office and its fittings, room, above all, is necessary. A cramped office means great waste of time, and in too small an office it is impossible for a man, when leaving one job to proceed with another, to return and find his work as he would wish; yet interruptions are frequently necessary. It is also extremely difficult to view drawings in their proper relation one to another

if there is no room in which to spread them conveniently. An allowance of 75ft. super per man, inclusive of gangways, may be taken as a convenient, though not an arbitrary figure. A method of arrangement is suggested in Fig. 1, where, by turning round, all one's data and drawings may be found at hand. A chest of drawings for current work should always be handy, but a means is necessary to prevent standard tracing sheets from taking up a permanent abode in this chest. The author is of opinion that drawing boards should be of the adjustable rise-and-fall type, substantially built, and, as a personal preference, fitted with a universal drafting machine. These are the quickest drafting devices on the market, and have only one disadvantage, that of weight ; they are apt to tire one's arm, but this can be compensated for by placing the board at a low angle when on long spells of work.

Tables and benches should provide ample leg room underneath, and stools of about 20in. in height should be provided. It may be remarked that one obtains more accurate drawings on high-angle boards ; while, for tracing, a board with a parallel rule seems to be the most efficient. The best tracing instrument is probably a 45° celluloid set square, with its longest side about 7in. in length. A tracer can get over a great deal of ground with this simple tool without smearing the ink, with but very little practice. This is especially noticeable when shading for contour, a practice that is eminently useful in the scheme advocated. Reference drawings, card index cabinets, books and data of all descriptions, should be kept in such places as to render it unnecessary for anyone to move in order that another may come at the desired object.

It is not desirable that printing should be done in the office, as this is a fruitful source of litter and disarray. A print room should be provided as an annexe to the office. It is essential that the printing should be done by artificial light, and that the drying should be performed by mechanical means, otherwise it will be found that there is a distinct time lag between the making of the tracing and the arrival of the prints at their destination. The object of making each draftsman as comfortable as is consistent with his work should be kept in view.

Standardisation is the mainstay of drawing office system. Standard methods can be applied in more forms than those concerned by shape and size. Such methods as will form a mnemonic key to the whole of the personnel of the factory should be employed in standardisation, in numeration and in nomenclature.

A few examples taken at random will suffice to show in what fashions standardisation, may be employed :—

One very common standard is the use of the diametral or millimeter module pitches for gearing. Another rather less common example is that which may be employed when using

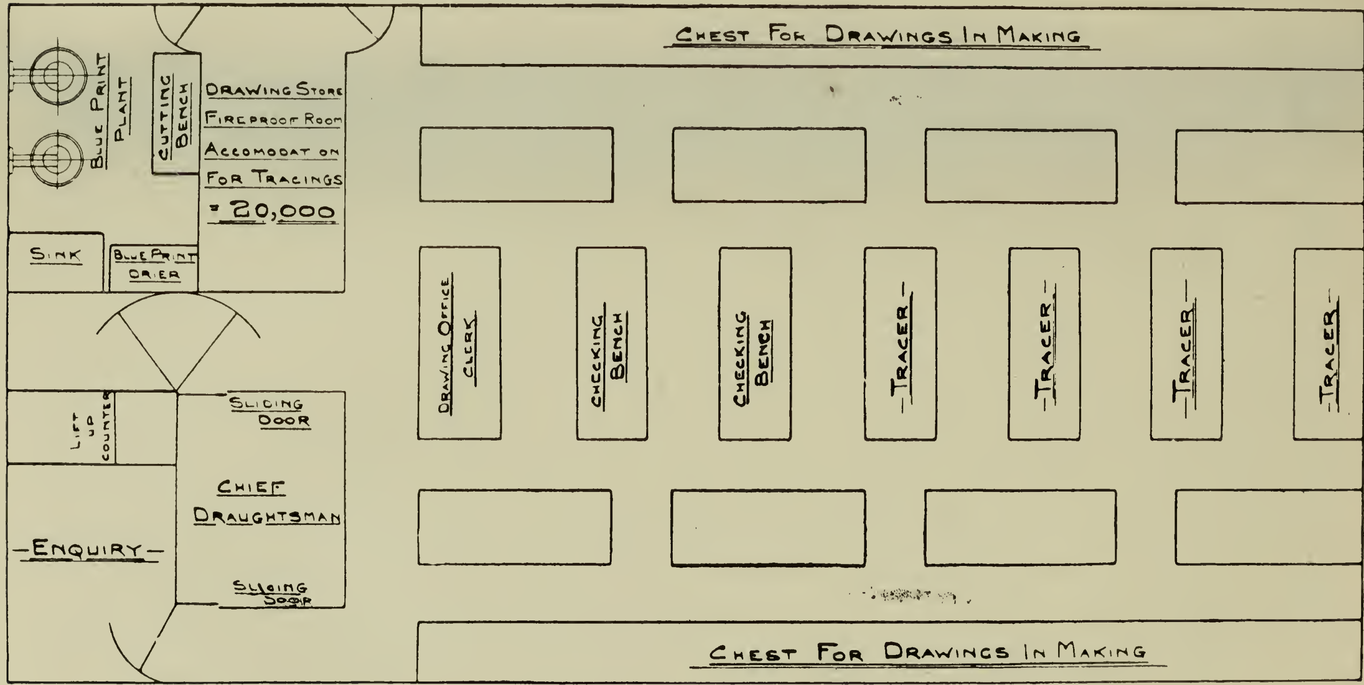


Diagram Of Drawing Office Arrangement

Scale $\frac{1}{4}$ = 1 FT

Fig 1.

castellated shafts. Let us suppose that one settles on a key 6m/m. wide, as a standard. If one adopts this, with a resolve that nothing will cause a departure from the standard, it is known in the drawing office, in the view room, in the factory, and, in fact, in every department that is concerned by these dimensions, that all castellated shafts must have a core circle with a circumference a multiple of the width of the key by 2 by the number of keys.

$$i.e., \text{ castled shaft core circle diameter} = \frac{6 \times 2 \times N.}{\pi}$$

If the height of the key be fixed at 3m/m., the outside diameter will be the foregoing formula plus 6m/m.

$$\text{Again, castled shaft outside diameter} = \frac{6 \times 2 \times N}{\pi} + 6.$$

The jig and tool office will know that if they provide drifts and cutters up to the largest diameter of shafts likely to be used, and graduated by the fixed amount that is automatically settled by the standard key, they will cover the needs of all the work that can be sent to them by the standard drawing office ; further, if the number of the keys on the shaft is taken as the tool number to be stamped upon the cutters and drifts, one would have a simple system which is understood by all the employés from the smallest lad up. For a third example we may take the method of standardising tapers due to Jarno.

Nuts, bolts, studs, bushes, keys, plugs, washers, pins, etc., may easily be standardised in reasonable "size-groups." The sizes should be *absolute* within the group.

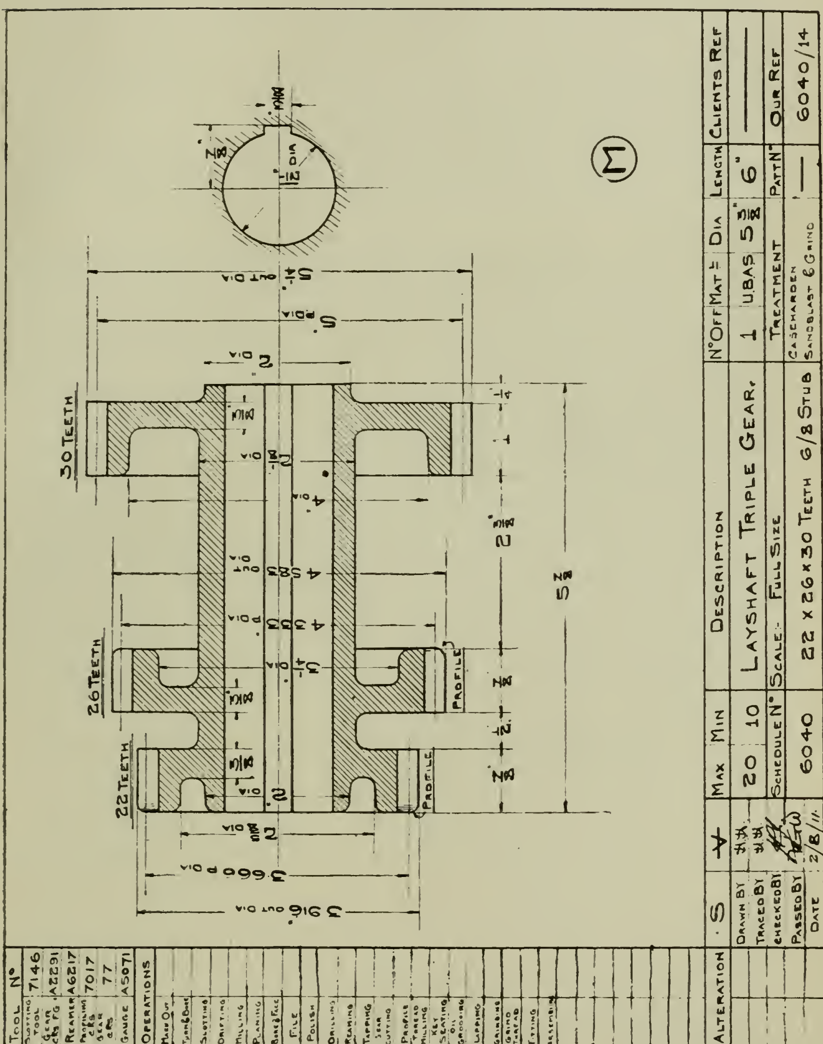
Objections are frequently raised to these methods as limiting design, but if the methods are thought out, and not adopted blindfold on "somebody's" recommendation, no such thing as limited design exists. Waste thought is limited, mistakes are limited, trouble is limited—anything but design is limited. We use "standardisation" a great deal as a cant word, but of actual standardisation there is really very little. It has been instructive to the author to query the methods of great manufacturing firms in this respect, with the result that he is amazed to find that form and size alone are considered in standardisation, and these factors but little. A factory comes readily to mind where stereotyped designs were employed ; small connecting rods for 100 h.p. engines would be the same shape as those for engines of 800 h.p., but where to obtain two standard grease plugs was a practical impossibility.

At the outset it is well to put in a standard set of gauges (Newall, for instance), and, if possible, to work to metric or at least to decimal sizes. It may be thought that the author insists too much upon standardisation, but in modern, complex, high-pressure businesses it is an invaluable adjunct to progress. It is

to be regretted that standardisation should still be parochial in its nature. It would be better by far if its influence could be felt through the length and breadth of the land, but, failing this ideal, it is surely not too much to ask that one might have standardisation within the factory.

Now, as to the actual making, checking and storage of drawings, it is, of course, for every individual firm to suit their own needs, and it is with some diffidence that the author approaches this aspect of the drawing office problem, more especially as he is unable to give to the inventor of the root part of the system advocated, the acknowledgment which he undoubtedly deserves. The system is based on the use of standard size, ruled and printed tracings to be used throughout the whole of the business.

Storage is a difficulty in all drawing offices, large prints and tracings are difficult to handle, and take up an enormous amount of room, the loose drawings of details are in the habit of losing themselves and are altogether undesirable. It is therefore necessary to adopt some method of filing and housing the drawings in such a manner that they cannot get adrift. This entails making them of a size that can be conveniently handled, not only in the drawing office, but in the factory and in every other department. After some consideration it appears that 15in. × 12in. is an exceptionally convenient size, and to the author a horizontal file, of the arch type, as sold by the Shannon Co., Ltd., appears the most desirable. It is possible to consult a file of detail drawings when stored in this way without disturbing a single paper otherwise than throwing it over the arch ; and when it is remembered some 6,000 drawings can easily be kept in a file cabinet about 16in. × 42in. × 18in. it will be seen that to provide fireproof accommodation for ALL the drawings in the establishment is a possibility and not merely an ideal. Two practical points are worthy of observance. They are, first, that the tracings should have a heavy, or rather strong, backing where perforated for the file; and, secondly, a heavy "weighting" board should be provided. Without these precautions tracings are liable to get crumpled and torn, though certainly the danger is not so great as in the old drawer system. The tracing sheets themselves should be bought ready bordered, ruled and with the holes punched. A specimen sheet is shown in Fig. 2, where it will be seen that spaces are provided for the Type, Number, Material, Treatment, Number off, Date, etc. Now these will not be placed where a new assistant might think that they ought to be placed, but will always be found in the same position, this point materially assisting the checker in seeing that all necessary information is on the drawing. It is also of the very greatest assistance to the man handling the job, either in the shops, the stores, or in any other place where the drawings may be used, to know instinctively where to look for information. The maximum and minimum column is for use



TRACING SHEET WITH DIMENSIONS.

FIG 2.

in the stores. It is found by many Works Managers that a set of drawings in the stores is a certain help to quick service of parts over the stores counter. This maximum and minimum column keys the drawings to the stock sheets. The column on the left which refers to turning, boring, drifting, drilling, etc., will be filled in by the estimating office for reference as to prices, by the piece-work office for reference as to times, and by the jig and tool office for the sequence of operations. Another column is provided for numbers of the tools used on the jcb.

It must be distinctly understood that none of these tracings will leave the drawing office, but to each department a blue print will be sent as required and these blue prints will be filed in that department.

Now, it is perfectly obvious that such a system as described, though keying all the departments together, would speedily become a nuisance because of that modern business curse—too much paper. Now, curses are not easily exorcised, but they can, usually, be handled with discretion. The most discreet method in the present case is to adopt the loose-leaf ledger method of filing. The catalogues of these loose-leaf books state that in a space of 6in. thickness 1,000 stout leaves can be held, so that in a cubic capacity represented by the area of our standard drawing sheet × 6in. we can store that number of prints. It is not many firms who, having standardised their small details thoroughly, have more than 1,000 drawings current in one factory. The advantage of this system does not end with the abolition of loose drawings. One could multiply useful examples along every line of activity, but let one other case serve. It is very often most desirable that estimating records should be kept secret, especially with reference to estimated piecework times. It is also desirable to have these, as previously suggested, written in on a print of the job, in order to make a complete record. Both these advantages can be easily attained by employing a locked loose-leaf ledger.

It is convenient, in working this system, for the drawing office to keep the ledger keys; they can then collect ledgers and add all drawings, at regular intervals, say once a week, in order that every department may be kept up to date. In cases where blue-print copies are needed before the end of the week they can be sent to that department, and incorporated on a loose-leaf file until such time as the weekly record is made. In order to weed out obsolete prints it is desirable that the ledgers be returned to the drawing office at least once a year, when the whole of the staff may be turned on to this work. One might suggest that the period during annual stocktaking would be a convenient time to effect this purpose. Superseded and cancelled drawings should not be withdrawn until the annual clearing. They should be stamped in large block letters at least ⅜in. high as follows:—

SUPERSEDED

SEE DRG. NO......................

across the face of the blue print, the reason for cancellation being added on the drawing thus stamped. This reason, of course, is only added to drawings belonging to departments to which a reason for cancellation may be useful. The new drawing, should be placed immediately at the back of the superseded one, thus constituting a complete record.

To link all the details to the body of the work in hand, the author suggests that the general arrangements be scaled down, and traced in the heavy style frequently used for book illustration purposes, and it is in this relation that contour shading is so useful. This shading may appear waste work in the drawing office, but it saves much time on the erecting floor, and also in those departments where men are not trained to read drawings.

One of these tracings can have the main dimensions drawn in, and another can have the detail numbers attached, so that the position of the details in the whole can be readily located by those assembling the parts.

In addition to these general arrangements, a schedule of parts should be provided before each group of details in the design. It will be useful to take as an example for this an automobile chassis, which can be conveniently grouped under the following headings: ENGINE; GEAR BOX; REAR AXLE; CHASSIS; STEERING; CONTROL; ACCESSORIES AND SUNDRIES. On taking up the complete file one would discover first a title page, thus in description:

40 H.P. CHASSIS

4-CYLINDER: 4-SPEED,

etcetera, in description.

SECTION.	PART NOS.	
Engine (parts)	1	100
Gear Box	101	200
Rear Axle	201	300
etcetera.		

The next sheet would be "Engine Schedule," as in Fig. 4.

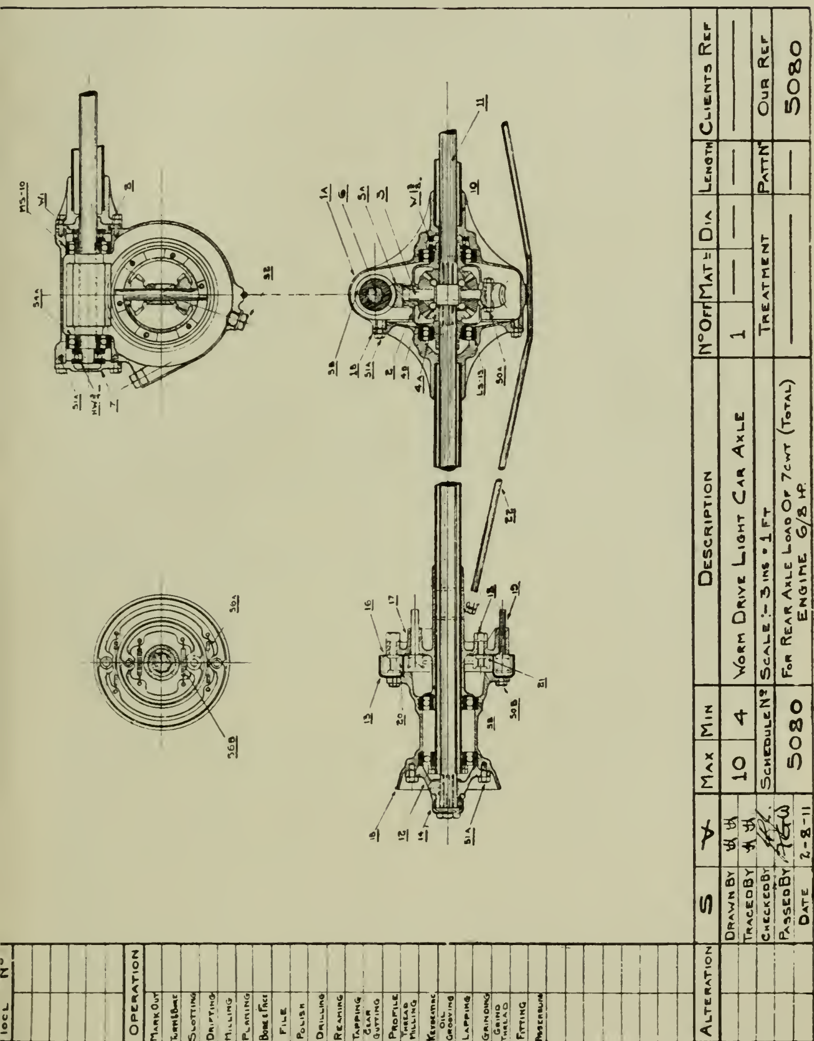
Following this would be the outlined diagram of the engine gear box, or axle, as the case might be, with the part numbers, as in Fig. 3. On the next page would be the same diagram, but with the main important dimensions marked in, and without the identification numbers. Following this one would find the details in the order indicated by the schedule, which thus also forms an index to the prints.

In order that sufficient information can be given on the prints for the machinist, and that they may not be unduly crowded, it is as well to have two sets of tracings for use where castings are needed, one of these for patternmakers' use and one for the machinist. This ensures that neither the machinists nor patternmakers will be troubled by a lot of dimensions that are quite immaterial to them. This duplication of tracings seems to harass folk who have never employed such a system ; it seems to indicate to them that a great deal of work is being done, uselessly, by a non-producing department. It must, however, be remembered that the tendency is to draft general arrangements to a large scale or full size wherever possible, and from these large or full-sized arrangements, details can be scaled down by any competent draftsman, who would proceed to figure in black ink for the patternmaker and in red for the machinist. His drawing can then be taken in hand by the tracer, who would make two tracings of the job. In such cases, by no means infrequent, when it may be necessary for the pattern prints to precede the major portion of the work, the machinist's print may be made at leisure (relatively to the job), when the pattern is once in hand. That the tracer has not to mess with bordering, etc., makes up for the time lost in making a second tracing, and the fact that the patternmaker's tracing is only used by the drawing office, and by them only when an alteration is contemplated, ensures that time is not wasted in the factory in puzzling over useless figures. This removes the fear of time wasted by this method as compared with the older system.

Should any addition or alteration be contemplated in the drawing office, for which there will be need to have recourse to the tracing file, the file should be taken from the drawing store, or strong room, entire, and tracings should not be removed from the arches of the file.

There should be a strict rule in the office that every file shall be in its place five minutes before the office closes, and then if a consecutive numbering system be adopted, it is possible to detect immediately the misplacement of any tracing.

With regard to card index cabinets in which general information, formulæ, etc., are kept, it is essential that the cards should be loosely packed so that it is possible to read them in place. It will then be advantageous to keep the drawer rod locked, so that reference can be made readily enough, but no cards can be ab-



TRACING SHEET WITH IDENTIFICATION NUMBERS.

FIG 3.

stracted. These cards should be numbered consecutively, as this would immediately render apparent the malicious or careless abstraction of a card.

If the drawings are of the dimensions suggested a very convenient method of handling them in the factory, is to have a number of zinc cases made with fronts of celluloid or other transparent material. These frames can be set up by means of a simple bracket at such an angle that the machinist has them before his eyes all the time. He has then no need to leave the handles of his machine to refer to his blue print, and the celluloid front will prevent the blue prints from being spoiled by oil or dirt.

The author here wishes to make an appeal for a definite engineering nomenclature, not necessarily for all the engineering trades in the beginning nor even for one branch of the trade or profession; but if it were possible to arrive at this ideal, even within ONE factory, a great result would have been attained. Definite nomenclature cannot be arrived at by issuing manifestoes from the office; it is not possible to arrive at the desired result by issuing orders that henceforth certain parts shall be called by certain names, which have been settled on the spur of the moment, or as the result of a happy thought. Education to a standard nomenclature is best attained by carefully wording all the schedules, by emphatically discouraging loose terms in the drawing office, and by ensuring that all the schedules and the drawing titles correspond.

A bad habit exists in some factories of providing long legends as titles—"Bush to rod actuating fourth speed gear," or "Grub screw securing connecting rod cap bolt" are two flowery examples. The smaller the part the more grandiloquent the title. This tendency to prolixity should be severely discouraged, and titles on drawings should have a snap about them. They should be essentially descriptive.

A great stride has been made when one can automatically ensure that similar parts on similar jobs get the same numeration and nomenclature, and also that important parts will have important or striking numbers given to them. Numbers ending in 0's are more easily remembered than numbers ending in other figures, and peculiar groupings of figures have a knack of sticking in the memory; they appeal to one much in the same manner as an unusual written word would appeal—one visualises the whole. This phenomenon is very useful when endeavouring to construct a keyed and easily remembered system of numeration throughout a large system either in works or factory. A method employed by the author as a stop-gap, while considering the best plan of numeration, was the employment of such numbers as 2000, 2020, 2030, etc., to represent a type of machine. Such numbers as these are readily called to mind. Any departure from the machine in the group would be expressed by adding

Pt No.	Description	Mt	[illegible]	Total Rec'd	Out Of	No. Rec'd	Rec'd By	Date	No. Rec'd	Rec'd By	Date	No. Rec'd	Rec'd By	Date	Weight	Rate	£	S	d	Remarks

Client	S.O. No.	Sets Off		Date Issued	Sheet No.	Schedule No.

SCHEDULE.

Fig 4.

the unit to the original figure, for instance, supposing a type of machine was grouped under No. 2020, and that certain small departures had been decided upon to satisfy another customer, this departure would be represented by the number 2021. In such a way one can obtain 19 departures from the original, and when one is faced by the fact that more than 19 changes are apparently desirable, one is forced to the conclusion that another design is necessary. It will be found that workmen readily adopt and follow this and similar plans.

Under the group numbers the part number, always agreeing, can be arranged thus (to return to the original example), 2020/1, 2020/2, etc. Where two parts occur on the same drawing, because they are so intimately connected with one another that they cannot be separated (such as the top and bottom half of a gear case, which must, of course, be bored together) a letter reference may be used, and in such a case we should have 5020/1A for the top half, 5020/1B for the bottom half. (A) for the top half and (B) for the bottom half would then be a standard form of calling attention to the position of these parts, and similarly with regard to right and left-hand parts.

In cases where there are on the books a great number of customers who require a diversity of small parts, a useful method of numbering is to utilise the firm's file number, under which the correspondence and orders can also be found.

These methods are only thrown out as tentative suggestions. They have worked well in practice, and would, if pushed to their legitimate conclusion, be great time savers. Where a firm is an operating company, such as a motor cab company, or a large manufacturing concern with a number of clients each with different wants, the file system indicated is most useful when it serves to couple up the client and the machine to the business system of the establishment. It is in this direction, perhaps, that this form of system can be most appreciated.

These memory aids need handling with a great deal of discretion and much forethought. Their employment may tend to increase the staff needed in the drawing office at the beginning, but when the firm grows, and would in the ordinary way become an unwieldy machine on the technical side, the larger drawing office staff will have justified its existence, and will have become a frictionless time-honoured institution instead of what, unfortunately, the drawing office more often is, a place of bickering and of doubt.

One might add a few words on the subject of catalogues, since it is most useful to have these a standard size. The author, however, experienced a shock, when collecting information for this paper, in discovering that every firm advocating system in business, used different sized sheets for catalogues. Some firms had apparently a different size of catalogue for every article stocked,

and even the size of letter sheets varied. Confronted with such a herculean task as systematising system one might be forgiven for thinking discretion the better part of valour.

Personnel.

In considering the staff it is clear that the most elaborate and perfect mechanism in organisation may be reduced to impotency, or even chaos, in a very short period, if the human element is neglected.

It is of utmost importance that all systems should be firmly controlled. If one does not rule the system intelligently, one will soon find oneself in the position of being ruled by the system—blindly. System, like fire, is a good servant but a bad master. It is not easy to find a good system, but when found its laws should be like those of the Medes and Persians. Endeavour that it shall be the right system, but if when installed it is not so good as was anticipated, hold to it inflexibly, remembering that a bad system, handled sensibly, is better than the most wonderful organisation mishandled. Especially is it necessary to be firm when commencing to systematise, because no immediate results, good or bad, can be apparent at once. The good points have a hard struggle before they show, and early errors have a knack of asserting themselves months after they should have been scotched. Both the good and the bad features will go on by their own inertia, and it is the organiser's task to foster carefully the good points, and to eliminate the bad, being constantly on the alert until an automatic stability ensues.

To this end, then, it is essential that the choice and control of staff should claim our attention. First of all, it is necessary to have men who are intelligent, progressive in thought, and facile in expression. A knowledge or experience outside their actual work is desirable, tending as it does to broaden the outlook. Most necessary, indeed, is an outside interest which will detract from the high-pressure work of the day.

The men who fill our drawing offices to-day are young—mostly too young. The drawing office is merely an incident, as a rule, in the training for a specialised post. This is to be regretted (when viewed from the point of drawing office organisation). It means that the older draughtsmen are frequently regarded as failed candidates for better positions, inasmuch as they are put into competition with an increasing number of men, fresh from technical colleges, who are in a position to accept a pittance in order to obtain a start in their profession. All this is in the natural order of the reversion from the old apprenticeship system to the college-trained engineer. It is necessarily difficult to ensure smooth and even results when drawing offices are peopled with an ephemeral staff. To combat this tendency to rapid change it seems necessary to offer a wage

inducement rather above the average at present paid to draftsmen. This is, judging by the mechanical engineering trades standard, somewhat under the rate set for a mechanic. The wage inducement that could be offered would not, of course, restrain the man who was to make a mark in his profession, but would simply tend to steady the market in good draughtsmen. What the actual wages should be must be left to the individual employer to settle, the author preferring to leave the further discussion of this point to the economist.

It is in connection with this floating population in the drawing office that properly organised routine proves its value. All new comers are obliged to toe the line in conformity with the regulations of the office, and, as previously explained, information cannot be omitted without the checker being aware of it. A phenomenon noticed by all who deal in systems is that system, although just, is absolutely ruthless where a waster is concerned.

The next factor to consider is the hours that the staff should spend at work. There are a great number of factories the managers of which are of opinion that draughtsmen, being a link between the factory and the office, should work factory hours. This, on the face of it, is apparently just. It is certainly a matter of expediency, since it is frequently troublesome to have a department, to whom all have to turn for information, out of office when the factory is at work. To have need to resort to the drawing office at all hours of the day or night (for overtime has to be considered) simply argues insufficient staff or mis-management. It should be remembered also that although a draughtsman's work is not physically arduous, it involves an attitude of mind continually on the alert, receptive of new ideas, and quick in embodying them ; hence work at high pressure over 7 to $7\frac{1}{2}$ hours per diem, with the necessary occasional spells of overtime, is sufficient if the desirable high standard of excellence is to be maintained. In the author's personal experience the greatest number of mistakes met with have been with staffs working full factory time, viz., 54 hours per week.

The question of temperament is probably the hardest to deal with. In order to obtain that smooth running conducive to the best work not a little attention must be paid to the psychological aspect of organisation. It may be taken for granted that the office is well ventilated, of equable temperature, and as comfortable as can be reasonably expected ; for the company that houses its staff badly, and expects the best result in the matter of work is in the same class as the man who permits his machinery to rust in the open, and is surprised to find that its efficiency is impaired. Such a firm is an anachronism in these days, probably existing only because of its own inertia, and likely to be relegated to limbo with all other antiquated stock in the course of a generation or two.

Given, then, that there is no physical cause for dissatisfaction, that remuneration is reasonable, there still will be (it is humanly impossible to avoid it) times when one or another will become discontented. To obviate discord it is necessary, whilst dealing firmly with any breach or misdemeanour, to discover why and how the grievance had originated, and if possible to remedy any defect in the system that may be brought to notice. There is one almost infallible method of preventing dissatisfaction, and that is to give all the staff some real interest in the work that they are carrying out.

This happy result is probably best secured by discussing the work with the individual preparing the drawings, by pointing out the advantages of the line of thought pursued throughout the work, as opposed to other perhaps more obvious methods. By showing how costs can be kept down, by the exercise of thought, how certain adaptations may render machining unnecessary, a hundred and one other points of interest will occur readily enough to anyone in charge of design work.

The great object served by all this is the avoidance of secretiveness. Secrecy is usually unnecessary, and should not be encouraged. It leads to the construction of those watertight compartments to which reference has been made. It is quite impossible, for instance, for anyone to take an intelligent interest in cheapening production if, on application to the piece-work or estimating departments for a comparison of prices or times, he is told to mind his own business. This does occur, and often, and although perhaps it is a small grievance, it is a very real one; the man thus rebuked probably retires to his drawing-board in a huff, and does not trouble about the costs at all in the future. It is not, of course, suggested that such information should be given in bulk, or to irresponsible persons, but when one is endeavouring to mould the mind of the workshop one must not refuse to supply data. It may be as well to remember that under modern conditions such data is really of little value in the employment market, and that trade secrets are scarcely existent to-day.

Unfortunately, it is necessary occasionally to reprimand an individual. This is a matter that should be between chief and subordinate alone. Slight as the reproval may be, it should be administered privately; to reprimand a senior in the presence, or to the knowledge, of a junior is simply inviting insubordination. Occasionally it is necessary, as a salutary measure, to make public comment on some action, but this power, if *seldom* used, has a most healthy deterrent effect when it is put into force. Beyond all things it is good to put away all remembrance of these unpleasant incidents. It is not accounted for as forgetfulness, although it may be regarded as a sign of clemency; in any case it puts the delinquent on his honour not to repeat the offence.

A few words on the state of the trade, in a general sense, the

race with competitors, and the likely trend of events are enormous factors in manufacturing enthusiasm. All these may be minor points, but they are just those points that will repay for recognition.

In arranging the work to be done it invariably falls out that certain individuals are more fitted to certain tasks. In the main it is a good plan to allow this natural aptitude to settle the choice of the man for the job. Care has, however, to be exercised that a just proportion of the interesting work shall be allowanced to all. Even with such care it is dangerous to let men specialise too thoroughly; not only does it tend to cause the work to run in grooves for the want of a fresh outlook, but should several of the staff be absent, for instance, on military duty, during the annual holiday, or from epidemic illness, the extra work on the remaining staff may mean disorganisation for several days, and perhaps months of hard labour to pull things straight again. Every chance, then, should be taken to render the individuals on the staff as interchangeable as the performance of their duties and their natural ability will permit.

The foregoing leads the author to the following conclusions: That to manage a drawing office successfully it is necessary to be well in touch with all other departments and to adopt methods that will key into them; that the office itself should be well and suitably furnished; that standard methods should receive far more consideration than they do at the present time; that standard nomenclature is useful, and standard stationery a crying necessity; that mnemonic aids should have an honoured place in the system; and that the staff should be regarded as a delicate machine, and treated as such.

THE MECHANICAL INSTALLATION AND UPKEEP OF PERMANENT WAY ON RAILWAYS.

By T. J. Gueritte, B.Sc., M.Soc.C.E. (France), Ingénieur des Arts et Manufactures (Diplomé).

[member.]

Introduction.

Until quite recently all the operations covered by the construction and maintenance of permanent way on the railway systems of the United Kingdom have been performed exclusively by manual labour, save only in respect of the delivery of necessary materials on the site. The formation of the ballast foundation, the placing of sleepers and rails in position, and the processes involved in fixing these and auxiliary fittings are done to-day very much as they were done in the days of George Stephenson. Despite the wonderful development of mechanical science that has taken place during the past century, permanent way construction is practically the only branch of engineering where the antiquated system of hand labour has not been superseded by machinery.

There are signs that this state of affairs may be shortly altered, for, thanks to the progressive policy which is exhibited by every department of the Great Western Railway, a trial has lately been made of the system of mechanical permanent way construction which has been in use in France since 1903. Mr. W. W. Grierson, M.Inst.C.E., the chief engineer to the Great Western Railway Co., having previously seen the process at work on the French railways, decided to make practical trials of the method on a few miles of track between Basingstoke and Bramley.

Historical Sketch of the Collet System.

The mechanical system of dealing with permanent way installation and upkeep which is discussed in the present paper was devised by M. Albert Collet, M.Soc.C.E., of Paris, and was first employed experimentally in 1903 by the Compagnie Paris-Lyon-Méditerranée. In consequence of the satisfactory report consequently made by Mr. Denis, Ingénieur en Chef du Service de la Voie, the company entered into a tentative contract for five years for the adoption of mechanical plant for the annual renewal of 100 to 200 kilometres of permanent way.

Work was commenced in March, 1904, at Chasses, on the P.L.M. main line, and was continued without cessation until the end of the year upon 105 kilometres of the track. In 1905 a total length of 119 kilometres was renewed on the principal lines of the system. The successful results attained induced the engineers of the Compagnies de l'Est and du Nord to make use of the system in the mechanical renewal of their lines, including re-adzing *in situ*, drilling, unscrewing and screwing bolts, and ballast packing.

The Compagnie de l'Est, having decided to execute the work with their own staff, hired the requisite plant, which was in use for two months on the Paris-Reims line under the direction of M. Muntz, chief divisional engineer. On the conclusion of the work, in May, 1905, the plant was transferred to the Northern Railway system, and employed in renewal of the Mereuil line, near Amiens, under the superintendence of M. Rossignol, chief engineer for permanent way maintenance. Other renewals on the same line were undertaken after completion of the first series in July, 1905. Early in 1906 the Compagnie Paris-Lyon-Méditerranée, having realised the advantages of the invention, confirmed their five years contract with M. Collet, stipulating that 150 kilometres of permanent way should be completely renewed each year by the mechanical plant.

As will be shown later, one special advantage of the method described is that it can be employed without the least interruption of traffic on railway lines already in use, another important advantage being that the ballast is so thoroughly compacted that trains can be run at full speed on the track immediately after the operation of packing, thus avoiding delay during the period of a week or more in which trains are required to slow down when passing over sections that have been repacked by hand labour. The latter characteristic appears to be fully confirmed by the observation of work executed on the three railway systems, and it is also worthy of note that the mechanical packing is far more lasting than that effected in the customary manner.

Having sketched briefly the history of the Collet system, the author will now describe the nature of the plant employed for various purposes in the application of the method to permanent way construction and maintenance.

Description of the Mechanical Plant.

The exact nature of the complete installation of plant required for the execution of the operations to be conducted depends upon circumstances. In all cases, however, the Collet plant includes a portable electrical generating set, a series of standards with power transmission cables, and a varying number of machines operated by electricity and supplied with current from the cables mentioned. The machines are placed in sequence,

FIG. 1.

conformably with the successive operations required to be performed. They are drawn along the railway line as work proceeds, and as they consist of small units they can readily be lifted and removed from the tracks, to avoid interference with traffic.

Generating Set.—Figs. 1, 2 and 3 illustrate the electricity generating set, which is mounted upon a carriage frame, provided with shafts and wheels for traction by road and with small flanged wheels for travelling longitudinally and transversely on rails. The set includes a petrol internal combustion motor (M)

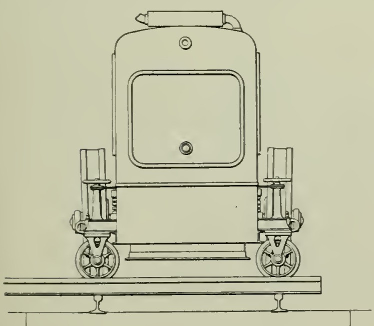


FIG. 2.

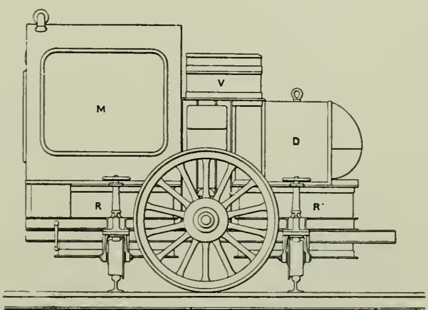


FIG. 3.

of from 23 to 45 h.p., according to the extent of the installation, direct-coupled to a dynamo (D) of corresponding power, which gives continuous current at 240 volts.

Two tanks (RR) are included, one for petrol and the other for water, the storage capacity being sufficient to ensure continuous working for the period of from 5 to 10 days without recharging. A water-cooling apparatus (V) is fitted between the petrol and electric motors, and all working parts are hermetically closed by an airtight steel hood. A characteristic feature of the generating set is the manner in which provision is made for transverse motion as an alternative to longitudinal movement along the railway lines. A lifting apparatus, akin to a screw jack, is fitted to the carriage, and by the aid of a crank one man can cause the entire plant to rest either upon the large wheels or upon the small flanged wheels, the latter being mounted so that they can be rotated on their axes through an angle of 90 degrees.

Supposing the generating set to be standing upon an ordinary road, it can readily be moved transversely after the large wheels have been lowered so as to permit traversing rails to be placed beneath the small wheels when the latter have been adjusted suitably, as shown in Figs. 2 and 3. Again, assuming the apparatus to be on a railway track in regular service, it can be moved out of the way in a similar manner for the generation of current, and moved forward on the large wheels, or, if more con-

FIG. 4.

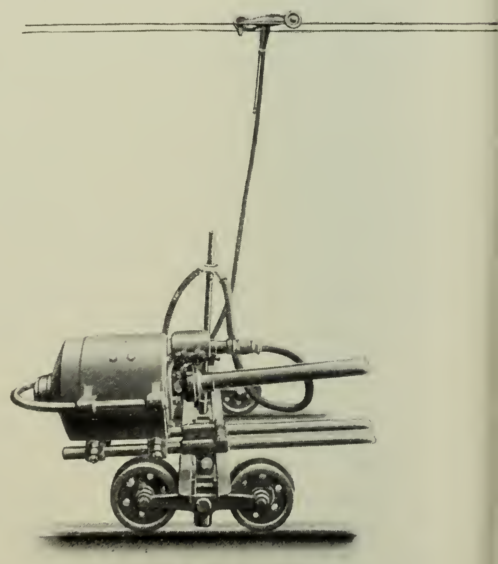


FIG. 5.

venient, it may be transferred back to the railway and moved along the lines to the next position, which is generally a mile away. This operation takes about five minutes.

Transmission Line.—One of the movable standards for carrying the power transmission cables is shown in Fig. 4. Its construction is very simple, and the standards can be set up in any position on embankments, in tunnels, or on viaducts, and even against walls if required. They can be placed in the 6ft. way should occasion demand, and may also be utilised as supports for electric lamps for lighting the works by night. A drum is provided for storing the cable when not in use. Each standard carries 165ft. of cable composed of two high-conductivity copper wires of 7/32in. diameter, the tension of the transmission line being controlled by the rest seen at the top of Fig. 4. Insulation loops are fitted as shown in the same view, and the current traverses the support through by-pass cables.

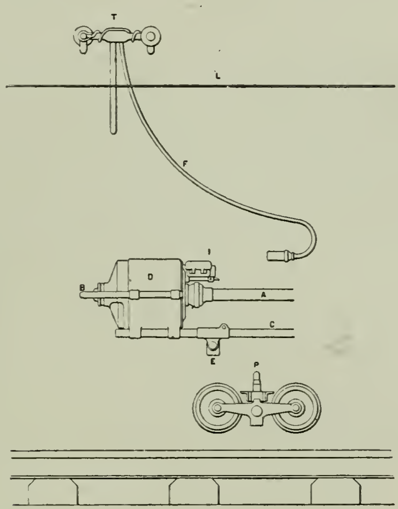


FIG. 6.

Any required number of standards are set up and connected by cable at distances of 165ft. apart in order to provide for operating the mechanical plant, and it has been found that two trained men can instal 4,100ft. of transmission line in one day.

Portable Electric Motors.—Each of the machines employed for boring sleepers, drilling rails, inserting bolts and screws and packing ballast is operated by an electric motor of 5 h.p. mounted on a small bogie and furnished with a trolley for the collection of current from the main transmission cable. By adopting a standard type of portable motor for the various machines maintenance is simplified, and the number of spare parts to be kept in stock is reduced to a minimum.

Fig. 5 is a photographic view of a motor, where the driving shaft is shown broken off. Referring to Figs 6 and 7, the trolley collects current from the transmission line, the cable takes current to the switch close to the motor, by which is driven the shaft connected at the other end with the machine to be driven. The

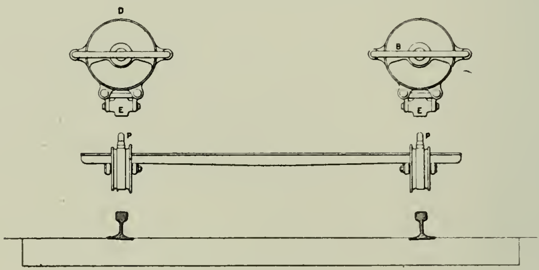


FIG. 7.

under-frame on which the motor is mounted has a step bearing receiving the supporting pivot of the bogie. The latter is formed of two articulated pairs of ball-bearing wheels connected by a cross frame enabling the two pairs of wheels to be spaced conformably with the gauge of the railway track. It will be noticed that as the various machines are employed in pairs, one for each line of rails, the complete bogie carries two motors as represented in Fig. 7.

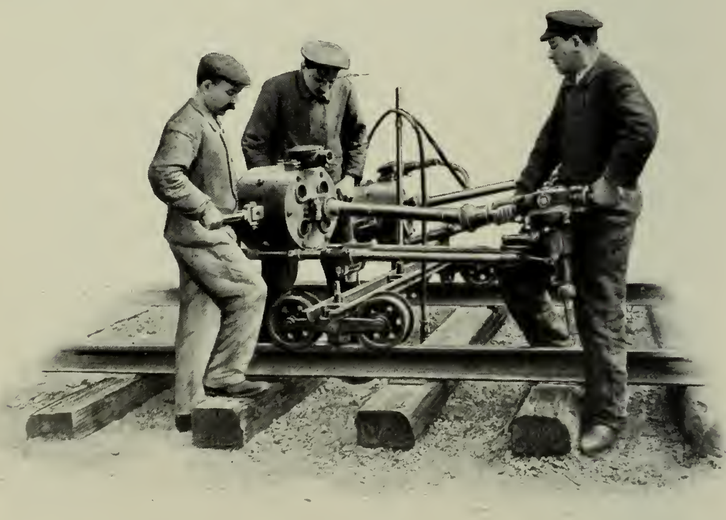


FIG. 8.

Each motor is fitted with arms by which it can be readily lifted from the supporting pivot, while the bogie carriage can also be lifted from the track without difficulty. This is a very important point, as it is absolutely necessary on railways already in service that the line shall not be obstructed. As each motor only weighs 3 cwt., and the bogie weighs 2 cwt., the work of taking all the machines out of the way can be performed quickly, and they can be just as easily put back and again set to work. It takes about one minute thus to clear the line.

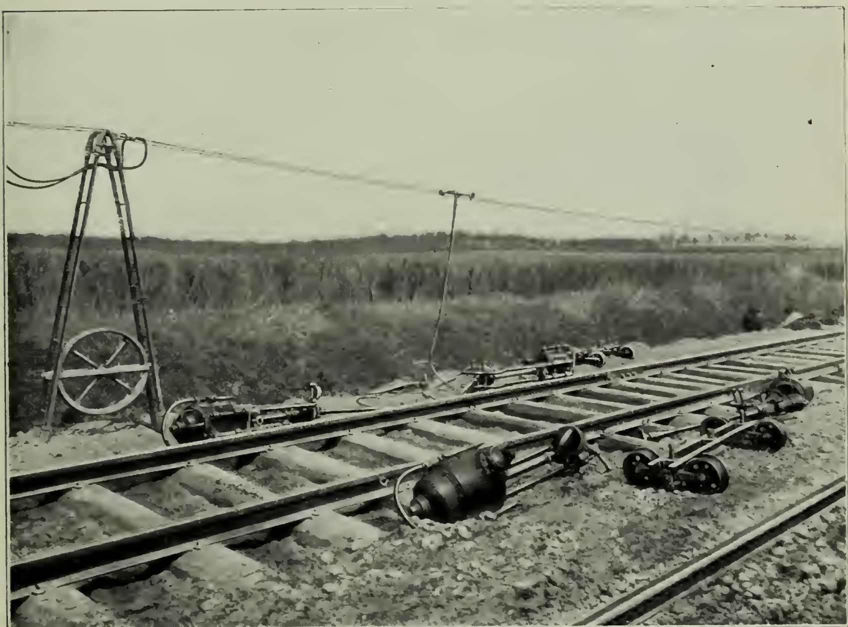


Fig. 8A.

Fig. 8 illustrates the removal of a motor with its connected machine, and Fig. 8A shows the track cleared for the passage of a train, the generating set and the power transmission line being already off the track but in close proximity thereto.

Some of the machines forming part of the complete plant as used on the Continent were designed for laying and relaying rails of the Vignole type, and consequently are not applicable, or only partly so, on lines where double-headed rails are adopted; but as members of this Society are called upon to deal with railways of all kinds, particularly in the Colonies and elsewhere abroad, the author believes that it will be interesting to give an account of the various types of permanent way plant as employed on the Continent.

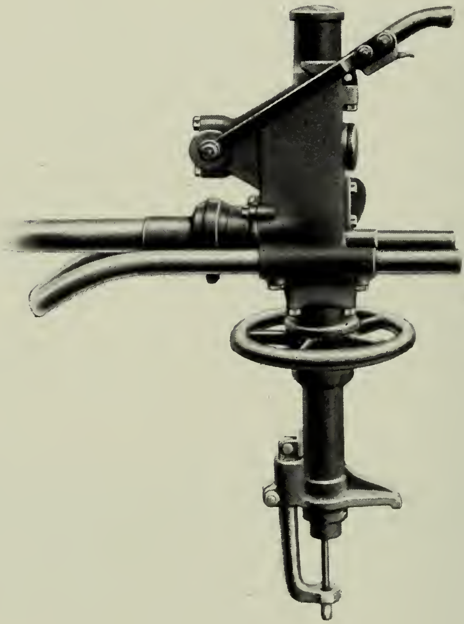


FIG. 9.

Boring Machine for Sleepers.—Fig. 9 is a view of the boring machine, connected with the portable electric motor by the horizontal driving shaft, the complete arrangement being shown in Fig. 10. The apparatus is designed for boring holes in sleepers

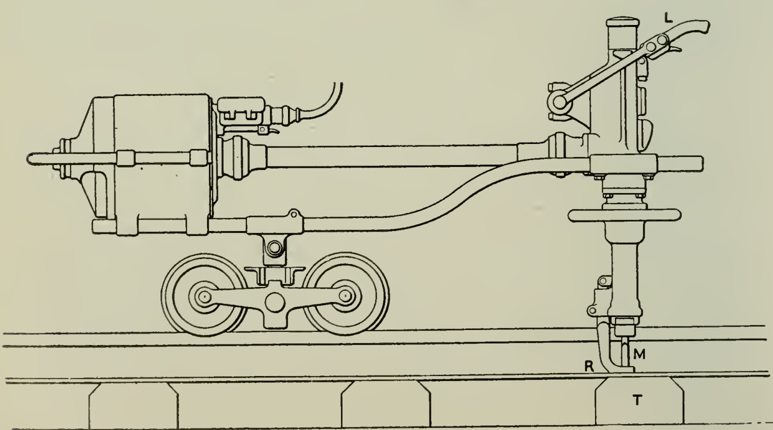


FIG. 10.

when clamped either to the rail, as in Fig. 10, or to a chair, and any inclination can be given to the boring spindle to suit requirements. The tool (M) penetrates the sleeper (T) to a depth governed by the stroke of the lever (L) ; the spindle rotates at 1,500 revolutions per minute, and the hole is bored in two or three seconds in the hardest varieties of timber. By clamping the machine in position errors are absolutely eliminated, while the mechanical operation of the tool obviates the oval-shaped and enlarged holes often produced by workmen using a hand augur, and so facilitates subsequent screwing. The apparatus is capable of boring about 250 holes an hour, its weight being 1 cwt. 1 qr., or 4 cwt. 3 qr. 9 lb. complete with motor and bogie.

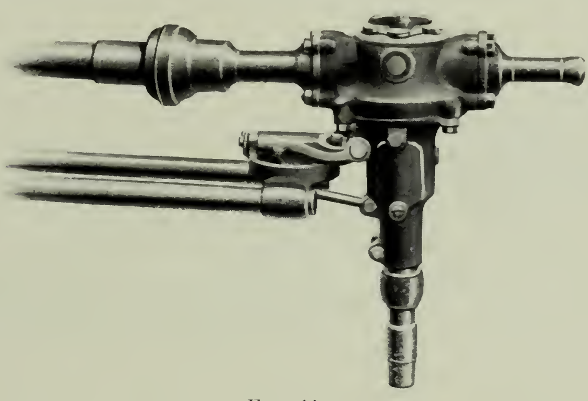


FIG. 11.

Screwing Machine.—Fig. 11 represents the head of the machine used for inserting and extracting screws and bolts, and Fig. 12 the complete apparatus. The frame (C), carrying the motor and screwing machine, is balanced on the supporting pivot

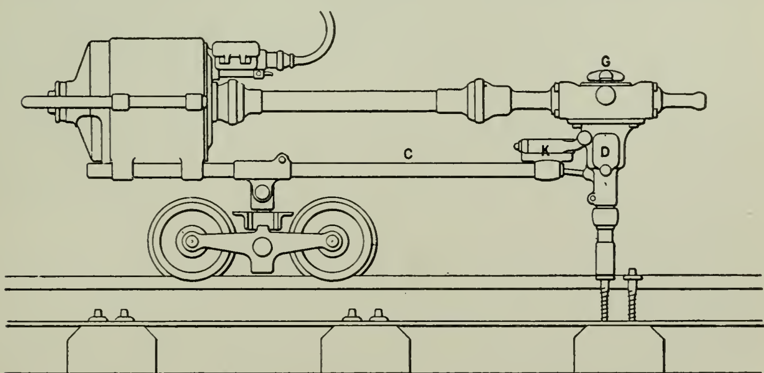


FIG. 12.

of the bogie carriage, and the universal joint (K) ensures the requisite mobility, enabling the head of the screw to be engaged even when presenting itself obliquely. The hand wheel (G) provides for reversing the direction of rotation so that the operations of screwing and unscrewing may be performed at will.

This tool develops considerable effort, so as to overcome the resistance of bent or rusty screws, and in order to prevent injury to the fibres of the timber an automatic release (D) stops the work as soon as any screw is driven home. The machine is operated at 550 revolutions per minute, and by its aid 500 screws can be inserted or extracted per hour. The weight of the head is 1 cwt., and of the complete apparatus, including motor and bogie carriage, 4 cwt. 3 qrs.

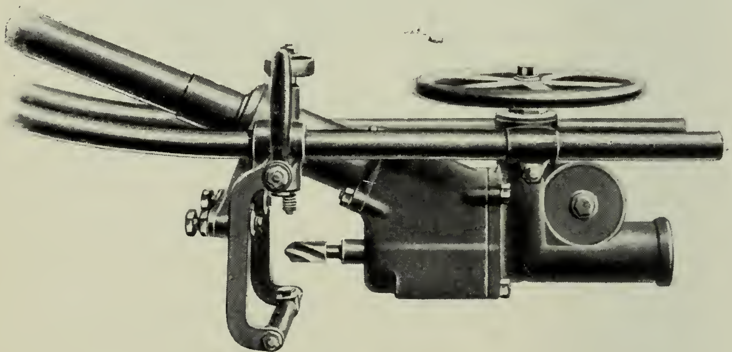


FIG. 13.

Drilling Machine for Rails.—Fig. 13 shows the head of a most useful machine employed for drilling holes through the web of double-headed rails. In this case only one machine is used on the track instead of one machine in each rail as before described. The machine is supported on the pivot (P) of the bogie carriage, as represented in Fig. 14, and can be swung round for operation on either rail. It is clamped by the device shown at (H), the drill (F) being fed by the hand wheel (V). The twist drill runs at 200 revolutions per minute, and is capable of making 40 holes per hour, or about ten times the number that can be drilled by a workman with a hand ratchet drill. The machine weighs 1 cwt. 21 lb. or 5 cwt. 14 lb. complete with motor and bogie carriage.

Machine for Packing Ballast.—This is in reality the most important of the various machines included in the plant for the mechanical construction and reconstruction of permanent ways. It consists essentially of a small ram actuated by the alternate compression and release of a powerful spring.

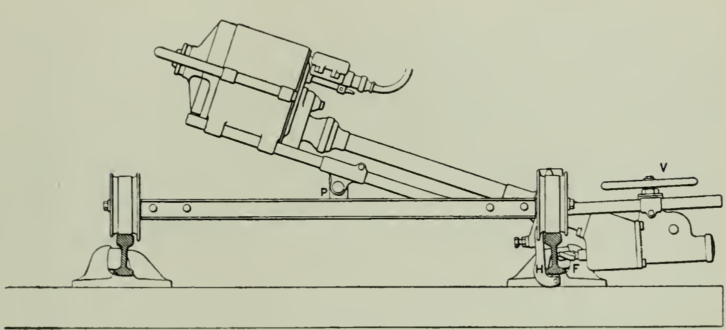


FIG. 14.

Fig 15 illustrates the ram as attached to the driving shaft and frame connected with the motor, and Fig. 16 is the complete apparatus. To the motor is added a speed reducing gear (R) so that the shaft rotates at 400 revolutions per minute, compressing a spring equivalent to a weight of 440 lb., enclosed in the head (C), the ram (P) making 400 blows per minute. The machines are usually employed in two sets of four on either side of the sleepers, the inclination of the ram being such that the ballast can be compacted beneath the sleepers to form a sound and lasting foundation. Experience shows that absolute uniformity of the filling is secured throughout the whole length of the sleeper,

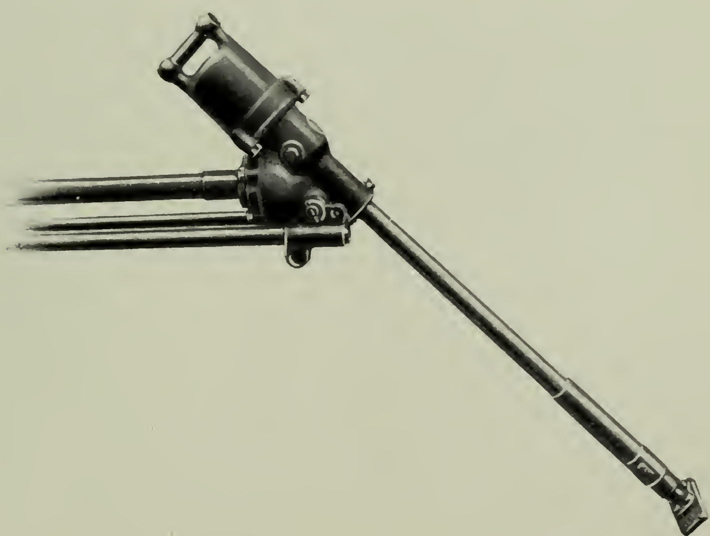


FIG. 15.

and that the solidarity of the rammed material is so remarkable that trains can be allowed to travel at full speed on the track immediately after the completion of ballasting. This advantage is one which particularly applies to permanent way renewal on existing lines, although it is by no means unimportant in new work. A still further advantage of mechanically compacted ballast is the economy attained in the way of maintenance, not only of the foundations, but also of the rails and auxiliary materials.

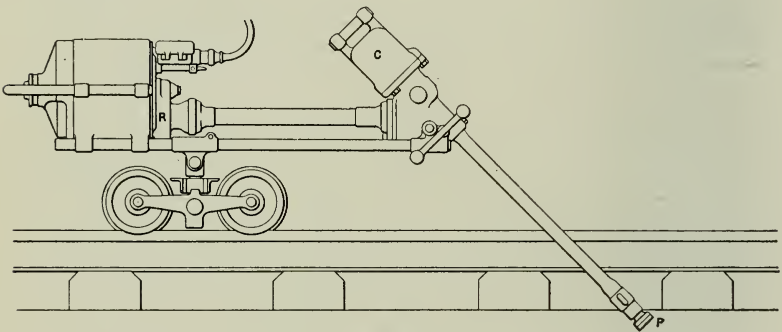


Fig. 16.

The output of two sets of four machines averages from 60 to 100 sleepers per hour, according to the thickness and nature of the stratum of ballast. The head (P) of the ram is made in various sizes and shapes suitable for different kinds of ballast, and as the head is detachable the same machine is available for work under different conditions. On lines where metal sleepers are used, the hollow underside of the sleepers can be quickly filled up and perfect packing ensured.

To illustrate the superiority of mechanical treatment the author gives in Figs. 17 and 18 two photographs taken during the carrying out of comparative tests of hand and mechanical packing on the Prussian State Railway near Eystruys Station, in Hanover. Fig. 17 shows the customary method of compacting ballast by hand labour, and Fig. 18 the work as done by machines at the rate of 40 seconds per sleeper. The packing machine weighs 1 cwt. 21 lb. alone, or 5 cwt. 14 lb. with motor frame and carriage.

Adzing Machines for Sleepers.—One of these machines, as shown in Fig. 19, is a strongly built self-contained machine, the frame of which is mounted on four flanged wheels of standard gauge for transport by rail. It can be removed from the track by means of transverse rails after the wheels have been adjusted, as described in the case of the generating set ; consequently it can be brought close up to any stack of sleepers that require

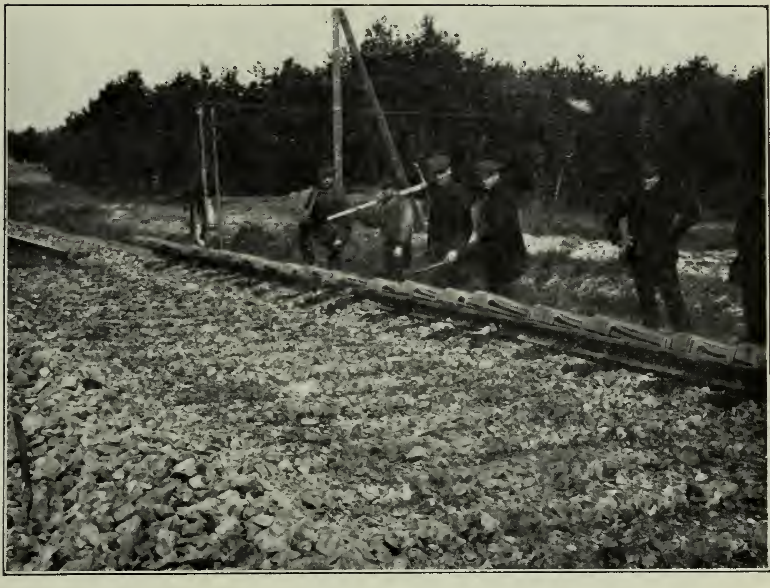


FIG. 17.

FIG. 18.

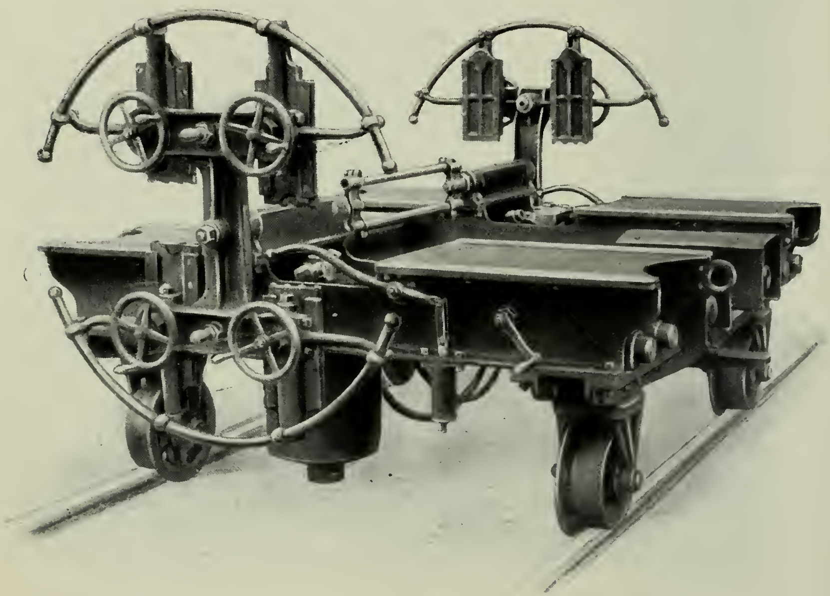


FIG. 19.

adzing, whereby considerable cost and unnecessary handling is avoided. This, of course, applies only to the railways where the sleepers are not adzed in well equipped workshops.

In addition to its mobility, this adzing machine embodies the new mode of working by milling cutters. According to the nature of the wood and the depth of the cut, the output of the machine ranges from 1,000 to 2,000 sleepers per day of 10 hours. The cut is made by a high-speed milling cutter, which avoids marking and injury to the wood caused by the tools used in adzing machines of the usual fixed type.

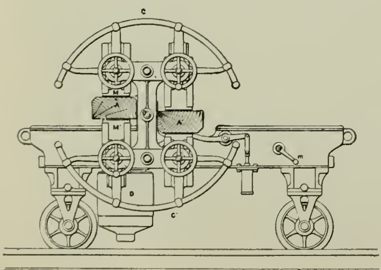


FIG. 20.

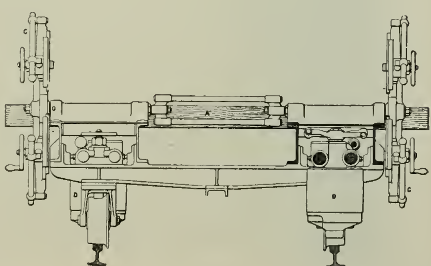


FIG. 21.

Referring to Figs. 20 and 21, the sleeper (A) is gripped between the jaws (M M′), and by rotating the circular railing (C C′) about the axis (O) it is brought to the position (A′). Then by means of the crank (M) two symmetrical milling cutters, direct-coupled to the motor (D), are caused to advance simultaneously on both sides of the sleeper, the requisite cut being made in 2 seconds. This gives time for the insertion of another sleeper at A, when the movements are repeated as before. The total weight of the machine is 2 tons 4 cwt.

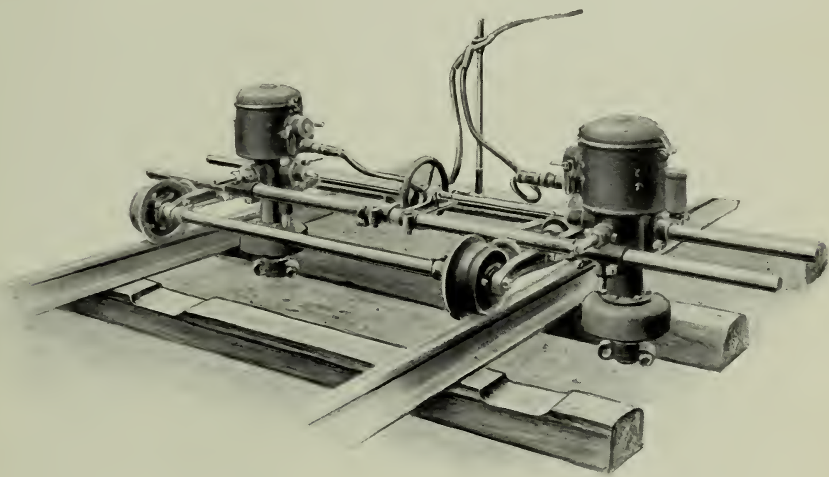


Fig. 22.

Fig. 22 represents an adzing machine designed for re-adzing sleepers in cases where there would be nothing gained by removing them from the track. As shown in Fig. 23, this machine is mounted on a bogie (B) and consists of two vertical electric motors (D D′) operating two milling cutters (F F′) lowered simultaneously by means of the hand wheel (V). The cut is made in two portions corresponding to short forward and backward movements of the bogie on the track while the milling cutters are in action. As the cutters go forward they cut part of the groove, then the whole system (DVD′) is moved transversely on the frame of the bogie, which is fitted with small runner wheels for the purpose, and travels only to the fixed length determined by the required width of the cut. It remains only to finish the cut by causing the apparatus to travel longitudinally in a backward direction on the track through the width of the sleeper.

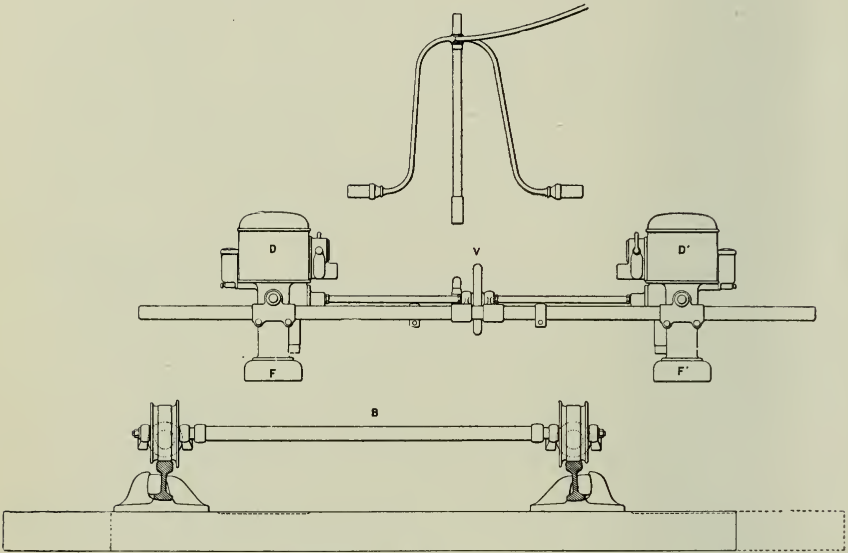


FIG. 23.

This reciprocating movement is only requisite in the case of sleepers intended to be used in connection with rails supported by chairs. For Vignoles rails the cut is made in one operation. This type of adzing machine, being specially designed for economy in permanent way maintenance, enables sleepers to be regrooved and the chairs to be refixed on the spot without taking out the sleepers, by simply pulling them out about 16in. transversely to the railway track. The process of re-adzing occupies only from 5 to 10 seconds, while a man with hand tools usually takes from 5 to 10 minutes to do the work imperfectly. The machine weighs 5 cwt., or 7 cwt. 2 qrs. with the bogie carriage.

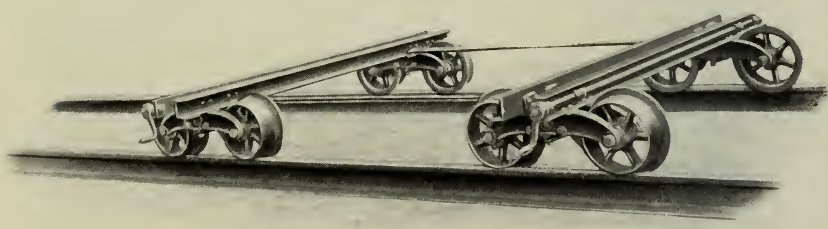


FIG. 24.

Auxiliary Plant.—Under this head the author purposes to describe briefly some very useful appliances which have been used with much advantage in conjunction with the permanent way machines previously mentioned.

A light form of truck for the transport of sleepers, rails, and other materials is shown in Figs. 24 to 26. It consists of two bogie units each fitted with a brake, the total weight being only 6 cwt. and the normal load 6 tons. Two men can easily push this load on the level, whereas an ordinary truck would require at least four to six men. Two men also can clear the truck away from the line, as each bogie weighs only 3 cwt., and the bogies are not connected together.

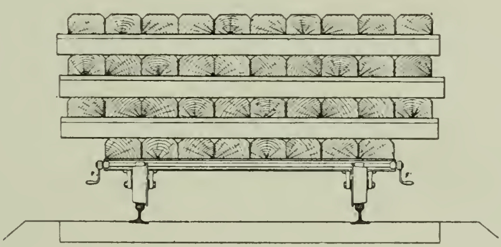


FIG. 25.

Fig. 27 illustrates a handy form of permanent way gauge, which can be fixed in a few seconds, and which, when in place, leaves the track free for traffic while maintaining the lines at the correct distance apart. A similar gauge is made for Vignoles rails.

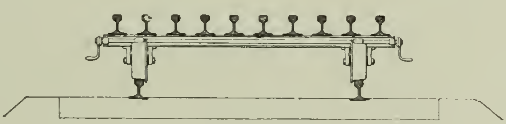


FIG. 26.

FIG. 27.

Finally, mention may be made of the workshop van, represented in Fig 28. This useful auxiliary is intended to accompany as closely as possible the mechanical railway plant, providing accommodation for the storage of spare parts and for workmen engaged in repairs. The van is mounted on flanged wheels like those of the generating set, and can be transferred to and from

the railway lines in the same way. For this purpose the screw jacks (V V′) support the van on the rails until the wheels (R R′) are turned through the angle of 90 degrees, the jacks playing the part taken by the large wheels of the generating set. The van is closed by an iron curtain (D), and is of suitable dimensions for transport on an ordinary railway truck; its weight is about 2½ tons.

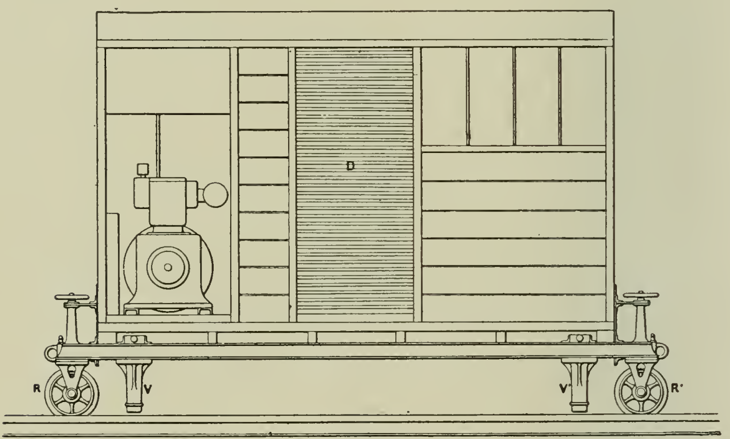


Fig. 28.

Conclusion.—The author hopes that in the foregoing account of a system for dealing mechanically with permanent way installation and upkeep railway engineers will find material not merely of interest, but also of practical utility. The method has definitely passed the experimental stage, as shown by the fact that although only applied in a tentative way as recently as the year 1903, the total length of railway track which has been laid and relaid by means of the mechanical plant described now amounts to more than 1,300 miles. The example set by France in the application of machinery to the important branch of engineering involved certainly appears to be one that should appeal with force to engineers in a country where the railways were originated and where the adoption of machinery to serve the needs of man has always been regarded as an important consideration.

2nd October, 1911.

H. C. H. SHENTON (VICE-PRESIDENT), IN THE CHAIR.

THE NECESSITY FOR SAFER, QUICKER, AND CHEAPER RAILWAYS; WITH SOME PROPOSALS THEREFOR.

By C. REGINALD ENOCK, F.R.G.S.

[MEMBER.]

IT is the purpose of this paper to inquire how far the present system of railway construction and working is keeping pace with the requirements of the age; and whether radical improvements are not both necessary and possible.

For all main purposes of passenger and freight movement the railway holds its own. We have perfected the motor car and developed the flying machine, but neither of these can replace the particular function of the railway. But, notwithstanding the great improvements that have taken place in railway science since the first locomotive ran, the railway is still too slow, too insecure, and too costly. Either we have reached the limits of its capacity, or else engineers are displaying a lack of ingenuity in its development. We are still killing and maiming large numbers of people on the world's railways; we are still unable to make such profits upon operation as will ensure railway operators a sufficient wage, passengers and freight a sufficiently low fare, and capital at the same time a sufficient dividend; and we are still halting in opening up the waste places of the earth, by reason of heavy cost of construction. All this may seem to be in the nature of an indictment, but if so it may serve to arouse discussion and stimulate thought.

About seventy years ago a line of iron rails was laid down, and a number of slightly adapted stage coaches strung together, and drawn by what was essentially the steam locomotive of to-day,* were caused to travel thereover. It was one of the greatest epochal achievements ever made; but to-day we are still travelling in what are practically a string of more or less insecure stage coaches, perched upon those same lines, drawn by a similar locomotive—a modern train, which can do little more than run along the bottoms of valleys, and that at high cost and with danger to its occupants. Such statements may appear exaggerated to the suburban railway traveller of Great Britain, and whilst, of course, they are meant to give point to argument, a survey of the condition of the world's railway systems will show that they are not

* The "Rocket" (1830) possessed the three elements of efficiency of the modern locomotive of water-surrounded fire-box, multitubular flue in boiler, and blast pipe, and direct connection of cylinders with driving-wheels.—ARTICLE IN THE "ENCYCLOPÆDIA BRITANNICA." (Eleventh Edit.)

unjustifiable. The railway has been, perhaps, the greatest mechanical friend of mankind, but that will not prevent our gratitude taking the form of a lively sense of favours to come.

Security.

The first element to be considered is that of personal security, notwithstanding that in railway construction in new countries this has taken a place secondary to that of development. It is a sort of popular saying in England that a railway carriage is one of the safest places in the world, and, relatively, this is not untrue. A less appreciative simile was that famous one of Ruskin, who spoke of "a carriage full of damned souls on the ridges of their own graves." Both statistics and general considerations must be taken into account, however, in the present argument. The following table shows the number of persons killed and injured from all causes connected with railway operation in the United Kingdom and the United States in the year 1907* :—

	Passengers.		Employees.		Other Persons.		Total.
	Killed.	Injured.	Killed.	Injured.	Killed.	Injured.	
United Kingdom ..	125	3,502	509	21,514	577	959	27,186
United States	610	13,041	4,534	87,644	6,695	10,331	122,865
					Grand Total	..	150,051

Thus, in these two countries, representing the extremes in railway matters, we have the heavy total of 150,051 persons killed and injured in one year.

These figures, of course, require examination in order to arrive at results which can be put down to accidents whose fault lies with actual railway science, for the greater part of such disasters are due to outside causes. Thus, for the year given, in the United Kingdom, only 18 passengers were killed and 534 injured due to actual disaster to trains in which they were travelling, whilst in 1908 no passengers were killed under that heading and only 283 injured, out of a total of 1,128 killed and 24,485 injured of all persons from all causes in that year.

Furthermore, accidents appear small when taken in comparison with the number of passengers carried, and for the year 1907 the ratio of passengers killed was 1 in 83,000,000, and of injured 1 in 3,000,000.

The employees, however, are far less immune, and as engineers we are equally concerned therewith. It has been calculated that

* Compiled from statistics in the "Encyclopædia Britannica."

in Great Britain one railway servant is killed every 16 hours, the shunters accounting for the greatest proportion. In the United States the slaughter is far more appalling.

To turn from effect to cause, the following were the principal causes of accidents in the United Kingdom in the year 1907 :—

Collisions (of all kinds)	405	accidents.
Derailments	589	,,
Trains running through gates at level crossings, etc.	364	,,
Fires in trains	170	,,
Failure of couplings	2,440	,,
Broken rails	289	,,

Including other causes of 24 enumerated varieties, the number of recorded accidents was 4,890, due to matters of rolling stock, vehicles, and permanent way.

Whilst, if we regard these matters from the point of view of statistics or percentages, we might feel called upon to agree with the "Encyclopædia Britannica" that railway accidents are already near their "irreducible minimum"* ; on the other hand we should maintain that so considerable a destruction of life and property ought to call forth greater effort and ingenuity in its prevention. We are constantly shocked by the occurrence of railway disasters, and engineers must refuse to take up a complacent attitude. It must often occur to the engineer when he beholds a heavy express train in motion, marks it rattle over points and crossings, sweep around curves, and brush within a few inches of platforms, that we are playing with mighty forces and are often separated only by a hair's breadth from disaster. This feeling is intensified when our work has taken us to where enormously heavy trains stagger across the high, insecure viaducts of the American West. It will occur to us that heavy locomotives at high speeds, on sharp curves, keep on the line more out of the kindness of Providence than by reason of mechanical laws. As we must contravene natural law by enclosing ourselves in fragile structures, to be hurled through space, we must see to it that nature takes the least possible toll from the contravention. Are we doing this ?

The determining factors in security may be described as two—the personal element and the equipment. In the United Kingdom we may congratulate ourselves on the careful and humane methods and excellent discipline in railway operation which are daily translated into terms of saving of life and property. In the United States it is the personal element that is largely to blame for the high ratio of loss and injury. Whilst the Americans are certainly the cleverest and most enterprising of railway builders, and have taught the world great things in railway location, their

* See "Railways" in that publication.

habit of taking chances, haste, lack of discipline, and subservience to money-getting bring up their sinister statistics to a high figure. A certain callous spirit of independence in the American character daily translates itself into terms of loss of human life and limb. It is scarcely a figure of speech to say that railway disasters in America began at the moment of throwing overboard the Boston tea-chests !* Of course, it is to be recollected that the enormous stretches of desert country crossed are factors in producing accidents, and to the credit of Americans be it said that their railways are the most audacious and colossal examples of the road-building art of mankind, both by the methods and rapidity with which they have been built and the method under which they were financed, and they deserve our admiration in this respect.

Thus it may be said that in the United States both the personal element and the equipment require improvement, whilst in the United Kingdom it is to a general advance, mainly concerning equipment, that we must look for improvement.

Remedies and Improvement.

These considerations bring us to the question of what improvement can be suggested in the permanent way and rolling stock of railways. A reference to the list of accident causes shows how large an item is furnished by collisions and derailments, and these undoubtedly give rise to the greatest loss of life and injury among passengers. Collisions occur on the best regulated lines ; and until we are in a position to change the present system, whereby express, local, and goods trains use the same tracks, they must be expected to occur. Pending this, however, are there no points of improvement to be aimed at in locomotives and carriages ?

Carriages.—If we examine a railway carriage intelligently we shall perceive that its structure scarcely fulfils the conditions for a vehicle designed to hurtle through space with a living freight at a mile a minute perhaps, and subject to the condition of being brought up sharply, as in a collision. A blow given at one end of this relatively flimsy structure reduces it to matchwood, and its occupants equally to dissolution in extreme cases. The reason of this faulty construction is evident. It is presupposed that a railway carriage will not have to sustain shock. As a matter of fact, a railway carriage has never got beyond the stage-coach period of evolution in this respect. But the question now arises if it should not be designed to resist destruction in collision. It is a common occurrence that the front or rear coaches of trains

* " Will nothing interfere with the American railroad's beneficent work of reducing its patrons to pulp ? Cannot American railway passengers be safeguarded as in England ? " the *New York World* asked recently.

are telescoped, and this is the most frequent cause of loss of life and limb, which would undoubtedly be heavier were it not that passengers distrust the front coaches, and prefer to occupy the centre or rear of the train. It is plain that some improvement is necessary here, that the ordinary railway carriage does not offer sufficient protection to its passengers. It is conceivable that a carriage could be so constructed that under the shock of collision passengers, although they might be shaken and injured, would at least not be maimed, mutilated, and burnt to death, as frequently happens at present, even on the best railways.

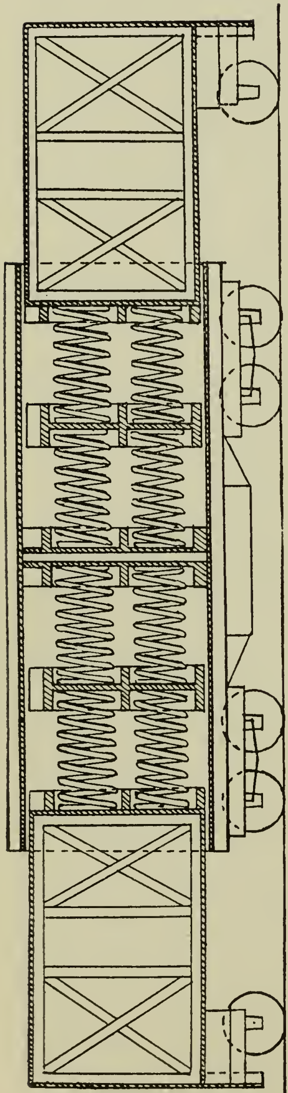
Shock-resisting Carriages.

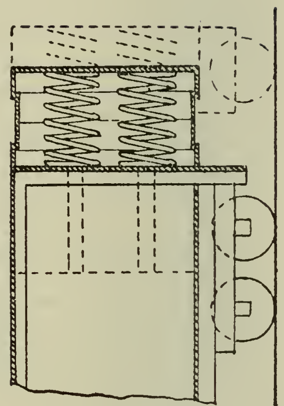
The proposal is here advanced that telescopic and crushing action in collision should be anticipated and provided for, and the author ventures to bring forward a design for a structure of such a nature, for criticism (see next page).

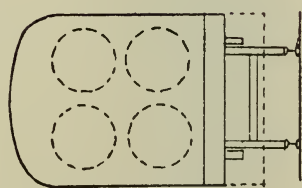
This calls for a carriage of three compartments, the two end ones, normally used as guards' or luggage vans, capable of sliding or telescoping into the central compartment, which contains a series of powerful coil springs, aggregating twenty or more feet in length, whose thrust would be given and taken by steel plates forming the ends of the compartments. This would give, in effect, a buffer resistance of the whole area of cross-section of the train plus the length of spring. The compartments would be formed of steel framing so strong as to be practically indestructible, and covered at the outer ends with armour plates reaching from the top of the carriage down to within a foot or so of the rails, whose function it would be to prevent the passage of wreckage, fire or steam. This special carriage would be placed at the front and rear of express trains, or, indeed, of all passenger trains, and in the centre also in the case of very long trains. An adaptation of the springs and armour plate could be used for every sleeping, dining or other coach if necessary. It is argued that the destruction of front and rear coaches in collision would be obviated, and the shock greatly minimised. The author has submitted this design to six of the principal railway companies of Great Britain, but none of them has shown any disposition to adopt it. This may be accounted for either by inherent defect in the plan, or by the traditional conservative attitude of English railway companies. We constantly forget the principle embodied in the classic reply that it might turn out " awkward for the cow "— that is to say, to refrain from condemnation without experiment, an omission to which our conservatism is somewhat prone.

The Lesson of Accidents.

Whatever system, however, might be adopted, the fact remains that greater security and strength in carriages is desirable. The details of accidents are liable to be forgotten, but we have







only to go back a few months to recall such. On Christmas Eve last a Scotch express was wrecked and twelve passengers were burned to death in the wreckage. In the official report the blame was placed on the signalman for having forgotten the two light engines left on the line, into which the train ran, and upon the drivers of the light engines for not sounding their whistles when kept waiting, and remedies were suggested against telescoping. Another recent accident occurred on June 24th, when an excursion train dashed at midnight into a siding, and was wrecked at the stop blocks. Due to the fact that the two front coaches were empty and locked, there were only eleven persons injured. In August a Birmingham express train crashed into a stock train, and 35 persons were injured. The first coach contained no passengers, which accounts for there having been no deaths.

In the United States express trains consist of heavy Pullman cars mainly, with lighter day coaches in front. These Pullman cars are exceedingly solidly constructed. " Always ride in a Pullman," said a railway inspector in the United States to the author, " in a collision they go through everything else," and, indeed, the author has witnessed the truth of the statement, where the front cars were telescoped and destroyed by the following Pullmans, which themselves remained intact.

The moral of many accidents is clear : we require for passenger coaches a different type of construction, and in train movement greater care and observation. Upon this latter point some suggestions are now offered.

Observation by Engine Drivers.

There is one matter in connection with the safe march of a train worthy of greater consideration and development. This is the matter of vigilance en route. A steamship has various officials whose sole duty it is to be on the look-out. On a locomotive the pilot, helmsman, chief engineer, and forward watch are all rolled into one in the form of the engine-driver, plus his stoker. The conditions, of course, are far from being analogous, but even then facts will seem to show that under present conditions the safety of a moving train is not under sufficient vigilance. The suggestion is here brought forward that locomotives, or at least the locomotives of express trains, should carry a specially trained observer in a specially constructed vantage-point in the front of the engine. Such an official might be, as regards technical knowledge and education, superior to the ordinary engine driver, with natural and trained powers of observation and concentration, and his eyes and ears would be constantly open for evidences of anything wrong ; and by an intelligent anticipation of events he would strive to avert accidents. Points, sidings, signals would be carefully scanned as

they were approached, possibly with the aid of binoculars in the daytime and searchlight by night. Obstacles on the permanent way might be detected or suspected by this close vigilance and power of observation, a faculty which too much of mere mechanics tends to minimise. The author ventures to think, after considerable experience with natives in undeveloped lands, that the natural or acquired power of suspicion and observation such as they display is not sufficiently cultivated in more civilised life, and that trained faculties of "scouting" of this nature would tend to avert accidents. The cost of added salaries would, of course, have to be considered, but the averting of accidents would more than cover such. Be it, however, as it may, a study of the causes of accidents shows that in many cases they might have been avoided by a more vigilant look-out from the engine. Here, also, we suffer from the stage-coach evolution at present.

Further matters connected with security are those of the high centre of gravity of rolling stock and curvature of the line, which are referred to elsewhere.

Speed.

We now come to considerations of speed, and it is here contended that we are not able to travel fast enough for the requirements of the age. The "Rocket" ran at 12 miles an hour. The author lives at a little more than 12 miles from London, and it takes him nearly an hour to get in by rail. This, of course, is not a fair analogy of speed, as local times are largely due to stoppages and changing. Nevertheless, even with what may be termed local express service, places 25 miles from London generally take an hour to reach, and to that must be added 10 to 20 minutes on the tube railways to reach the City or West End. Local transport is much bound up with social advancement. If we are to continue congregating in cities by day and leaving them at night we shall inevitably require transport which will take us farther away in much less time than at present. Of course it is highly probable that, as time goes on, conditions of decentralisation will bring about changes in railway travel and that the great ebb and flow to and from cities will cease to some extent. Already considerations of space are causing workers to go farther afield, and no doubt a time will come when the industries will follow the workers, and it may be said the sooner that takes place the better for social advancement. At present, however, we require greater local speed.

As for long-distance traffic, this is much slower than we might legitimately hope for. To reach distant points takes us too long. Following are some examples of daily railway travel taken from the time tables.

London to Edinburgh, 400 miles: Out of twelve trains daily there and back, on the L. & N.W. Railway, the average time is

9 h. 15 m., or an average of about 43 miles an hour. The quickest occupies 8 h., or 50 miles an hour, and the slowest 12 h. 18 m.

London to Manchester by same line, 183½ miles, and the time average of 31 trains is 4 h. 18 m., or about 43 miles an hour. The fastest takes 3 h. 30 m., or about 52 miles an hour, and the slowest 5 h. 55 m.

London to Plymouth by G.W. Railway, 226½ miles, with a time average of 5 h. 42 m., or about 40 miles an hour; the quickest being 4 h. 7 m., or about 55 miles an hour, and the slowest 8 hours.

London to Portsmouth, a distance of 73 miles, takes 2 h. by the quickest train; whilst from London to Brighton, 51 miles, the shortest time is about 1 hour.

Of course, these times are exceeded for short stretches in long runs, and the author has timed trains between Paddington and Exeter, on the Great Western Railway, at the rate of 4 miles in 3 m., but for all intents and purposes 42 to 44 miles an hour between our great towns is all that railway science can give us—speeds, moreover, that were attained many years ago.

In the United States the average speeds are still lower. It is true that the "Twentieth Century Limited," a famous express on the New York Central Railroad, covers the 1,000 miles between New York and Chicago in 18 hours, an average of slightly over 55 miles an hour, claimed as "the world's fastest and longest non-stop run." Also the other splendidly built and well equipped railways from the Atlantic seaboard to the Mississippi Valley and Great Lakes reach speeds not inferior to those of British lines. But in the West speeds are much lower, and probably the average is not more than 25 miles an hour, even where stations are far apart.

In general terms it may be concluded that the limit of practicable speed on steam railways has been reached under the present system, and if greater velocity is to be attained it will be by radical changes in permanent way and rolling stock. That conditions of increased speed are necessary will scarcely be questioned.

Cheapness and Economy.

To come now to the matter of greater cheapness and economy, two factors stand out—the great cost of building railways and the relatively high cost of travelling and freight haulage. If these matters could be reduced, both the business and social welfare and intercourse of the world and the unexploited parts of the globe would be capable of far more intensive development.

It cannot be said, however, that these high costs are the result of exorbitant profits made by railway builders or by railway shareholders, or of high wages to railway workers. Taking the year 1907, the return on the paid-up capital of all British rail-

ways, amounting to £1,310 million, was 3·32 % ; and that of the United States $16,082 million, 5·1%.

In 1888 the British dividend was 4%, and in the United States 3·25%, showing in the one case a decrease and in the other an increase to the present time.

For last year, 1910, the dividend on the paid-up capital of all British railways, amounting to £1,318 millions, was 3·48%.

In the United States the railway workers are paid far better than those in Britain, even when the added cost of living in America is taken into consideration. Nevertheless, the same conditions will be encountered sooner or later in America.

As regards high cost of construction or heavy capitalisation, this has been due in large part in Great Britain to matters of land purchase. It is one of the penalties we pay for our system of private land monopoly. In the United States, Canada, and Mexico vast areas of land were often ceded by Governments to railway companies as a subsidy for building, and in South America are still so ceded. The actual cost of construction of many of the well built railways in the Eastern part of the United States does not differ greatly from that of British lines. Yet the total cost in the one country is less than a third of that in the other, due to the item of land. The following calculation, for the year 1908, is made on a single-track-mile basis, that is, disregarding sidings, and shows the amount of paid-up capital per mile :—

	Single Track Mileage.	Paid-up Capital Per Mile.
		£
United Kingdom	39,316	33,333
United States	254,192	10,372

The present prospects are that construction and travel and haulage, rather than becoming cheaper, are likely, under the present system, to be dearer. As regards construction, the increased costs of wages and material are those which will tell. Whether the price of steel will be greater or less remains to be seen, but certain it is that the world's supply of timber is becoming depleted, and that cost has risen greatly and must still rise. This is due both to improvident waste and to other causes. In America forests have been cleared away, both for timber and fuel, and vast areas of stumps greet the traveller's eyes, whilst re-planting has been neglected—as indeed afforestation in Britain is neglected.

As regards wages, and consequently the cost of operation, the workers in Great Britain are not unreasonably demanding an increase, and higher rates may follow. The average pay of

railway workers in the United Kingdom is stated to be only 17s. or 18s., and it is a matter for surprise, not that a demand for higher pay should now be made, but that the demand should be made only now. The weekly wage of 100,000 railwaymen is £1 and under, and they work not less than 65 hours a week, and in many cases 72 hours. The matter of long hours, at least, concerns the safety of the travelling public, apart from humane considerations. No system of industrial civilisation can endure which cannot better provide for its workers. The author submits that it is time to consider whether we are not suffering from a "great illusion" in paying labour of all kinds as little as possible, instead of as much as possible. That higher wages would ultimately result in higher profits all round, the balance adjusting itself at its natural fountain head of a more intensive and extended exploitation and development of the resources of the globe. This, however, is not within the scope of this paper.* Recent events, the matter of railway strikes, have but accentuated what all students of our social system have long been aware of, that the well-being of society is dependent upon the well-being of the workers. Indeed, the indispensable part played in modern life by the railway has once more been brought home to the community. If we can cheapen the cost of its working we shall be able to pay a better wage, whilst still retaining a fair dividend for capital. We shall do more —we shall cheapen the cost of food and raw material. Under present conditions it is the cost of transport, not of production, of food products especially, which renders our food so increasingly dear. The author has seen loads of the finest fruit cast into the sea or left rotting in the fields in Western America, because the cost of its transport was prohibitive; whilst in Great Britain fruit is practically unattainable for the poorer classes for a great part of the year.

Another element to be considered under the heading of economy is that of half-empty trains. Any observer will note during the greater part of the day, on any railway, long trains with a handful of passengers scattered through them, and many empty coaches. Yet no effort seems to be made for swifter individual motor-carriages at the slack hours. Possibly there are reasons for it known to traffic managers; but it looks extremely wasteful to the engineer.

Topographical Considerations.

It is largely to topographical considerations that we shall have to turn for relief. At present we are overcome by topography rather than overcoming it. If it were possible to dominate steep gradients easily, a great part of the cost of construction would

* The author debated this point in a paper before the British Association at the last meeting of that body.

be avoided, curvature largely eliminated, and alignment simplified, with consequent diminution in friction, driving power, wear and tear, and danger of derailment and other accidents, as well as the shortening of distances. In brief, if it were possible to go over hills as well as round them much would be gained. Even in our railways over the comparatively level surface of Great Britain the enormous work and cost involved in cuttings and embankments is one of the most notable features of construction. To be able to haul a load up a gradient of 1, 2, or 5% even (the maximum at present) is a very inadequate means of traversing the surface of this indented globe. When we observe the ease with which a motor car surmounts a steep road we shall decline to think that greater capacities for our railways are impossible.

As to more mountainous countries, any consideration of the slow development of these, due to lack of railway transport consequent upon the present heavy cost of construction and the inability of trains to ascend steep gradients, will no doubt cause the observer to ask if it is not possible to evolve some other system. The extraordinary cost and difficulty of getting up mountains with railways depending upon simple adhesion is shown on every continent. The west coast of North and South America, for example, is cut off from the interior of those continents by the Andes and other mountain chains for more than 10,000 miles, with few passes under elevations of 7,000ft. for the northern continent and 12,000ft. for the southern. Typical examples of these difficulties are shown in the famous " loop " on the Denver and Rio Grande Railroad, over the Rocky Mountains, and the remarkable series of zig-zags on the Oroya Railway, reaching an elevation above sea level of 15,660ft., in the Andes of Peru.* Small haul, great fuel consumption, and high cost of maintenance are naturally features of such lines, added to the huge first cost.

In some of these mountain systems almost impossible degrees of curvature have to be resorted to, such as reduce both speed and safety to a minimum, and this feature will have to be eliminated in the future. It is to be recollected that mountainous countries are often extremely rich in minerals. In Peru and South America generally, in the Andean region, enormous mineral wealth lies unexploited from lack of means of transport—coal, copper, silver, gold, and all else ; whilst the wealth of the great basin of the Amazon in agricultural and forestal possibilities lies almost untouched for the same reason. Analogous conditions occur in many parts of the world. France and Spain are cut off from each other ; huge parts of India and Tibet are unexploited, and so forth.

How are we to get up these high places ? Will flying help us ? Not yet, probably, although in this connection the author has ventured to speculate somewhat, later on. Perhaps the future

* See the author's book, " The Great Pacific Coast."

will evolve for us some new possibilities of power in mountainous regions. Some difference of potential due to great elevations above sea level may become available. In the high regions of the Andes and elsewhere we have sometimes only half an atmosphere weighing upon us ; whilst the presence of electricity in the atmosphere is very noticeable to the traveller. Be it, however, as it may, we require easier access to mountainous regions, and it is time that engineers should apply themselves to the subject with greater exercise of imagination and ingenuity. Rack railways and cable railways do not appear to solve the problem. Possibly electricity will show itself of greater utility. Mountainous regions generally contain water power, and hydro-electric energy is capable of much development there. But withal simplicity must underlie all and any new railway system. The admirable feature of steam railways is their simplicity. There is no costly power house nor electric currents to be cut off, with consequent paralysis. The locomotive is a law unto itself, a self-contained unit, generating, under simple principles, its own power as it goes along, from the commonplace materials of coal and water.

There is, of course, a philosophical point of view of the matter of freight haulage, just as there is in the matter of local travel, as mentioned before. Looked at in this light, probably we are doing a great deal of useless hauling of food and articles about the earth's surface—things which might be used or consumed in their place of origin, or produced in the places to which they are carried. It is, in this sense, reminiscent of the activity of ants, which climb great obstacles with heavy loads in an apparently reasonless manner. Thus, Great Britain consumes great quantities of foods brought in over mountains and seas which she could produce on the spot to a large extent, and sends abroad great quantities of manufactured articles which might be, and doubtless will be soon, made on the spot by their present purchasers. There is little doubt that a large part of freight traffic on railways consists in " taking coals to Newcastle," and this is not likely to endure very long. It is, however, " a condition and not a theory that confronts us," and it is time for cheaper and swifter transport.

New Types of Railways.

If we are to attain to greater speed, security, and cheapness in our railways it can scarcely be doubted that some radical change in construction and form of permanent way and rolling stock must evolve. We have certainly not reached the limit of mechanical speed, as shown in their respective fields by motor cars, torpedo boats, hydroplanes, and flying machines, but we have reached the limit on the ordinary steam railroad. It is time at least to experiment upon new railway types. Upon what

lines is it possible that such might evolve? The question is philosophical as well as mechanical, and imagination must play its part too.

It is quite possible that lightness and mobility rather than heaviness and solidity will be the elements to be considered. So far we have cultivated the security and utility that come with *weight*: but it may be that security and utility with *lightness* will furnish a key to the problem. We may discover that the hurling of heavy masses of iron and timber through space, as practised with our present type of rolling stock, is unscientific.

Points which are strongly held up to our consideration in observing an ordinary railway are the cost of land over which it runs and the considerable area occupied and rendered useless thereby for other purposes: as also, the great amount of work involved in cuttings and embankments, the matters of ballast, drainage, culverts, bridges, tunnels, etc., the ponderous weight of rail and material in the permanent way; and great weight of the rolling stock; and the imagination endeavours to construct for itself some system free from these attributes. But what form could it take?

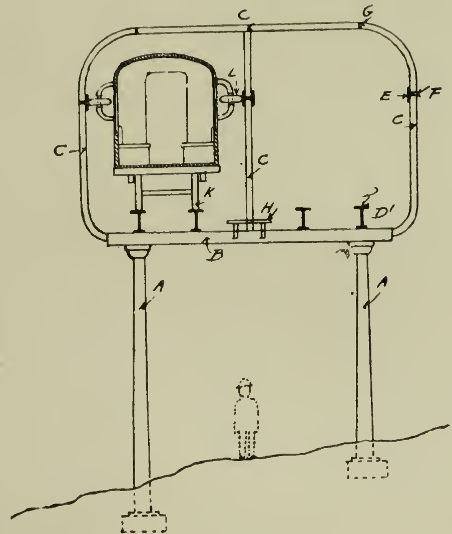
In the author's mind it takes the form of light, rapid, individual vehicles, rather than long, heavy trains, running at frequent intervals upon a light structure of uninterrupted line under conditions where collision and derailment would be impossible, rather than upon a ponderous and interrupted route; vehicles flashing from city to city at double or treble the present speeds, and at a tithe of the present cost. Such a vision, of course, requires to be brought into terms of cold practicability.

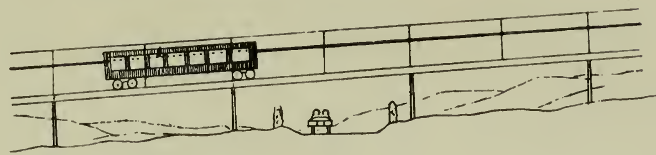
Light Overhead Railways.

It is possible that a system involving light overhead railways is worthy of consideration and experiment. Not, however, of the ponderous and unsightly type of structure which defaces the side streets of New York, but a structure in which lightness, appearance, and low cost were the elements for success. Such a line may be conceived as running across hills and valleys, consisting of little beyond light trussed steel beams carried on columns set in the ground at such a height as to clear ordinary obstacles of roads, hedges, etc.; and of a character such as would leave the ground beneath it free for agricultural purposes. Single light vehicles would run upon this structure at high rates of speed, and their stability upon the line against lateral movement would be provided for possibly by side wheels set horizontally above the centre of gravity, revolving against side rails. Thus such vehicles could not run off the line. The use of rubber tyres or some other method of increasing adhesion would enable these motor carriages to overcome the very steep gradients which the proposed system of crossing hill and valley in a more or less direct

Suggested Light Overhead Railway.

CROSS SECTION





SIDE VIEW OF RAILWAY

Explanation

A, C.I Columns B Cross Girder
C. Bent Tees or Angle Bars.
D, Flat steel plate, forming rail
D', Lattice or rivetted Girder,
E. Flat plate, track for horizontal wheels.
F. Channel or Tee framing
G, " "
H, Footway. K, Rubber tyres
L Horizontal wheels, rubber-tyred

line would involve. Instead of rails, plates might be used, and non-flanged wheels. Such structures would be, in effect, a species of elevated motor-roads, with the matter of steering eliminated. If such a system were found practicable it is easy to see how great would be the economy over the present railway, especially in the matter of earth-work, fencing, tunnels, bridges, telegraph posts, drainage, etc., all of which would be eliminated, and the occupying of land, which last item in a country such as Great Britain must become of growing importance. That our future railways must always cost us £33,333 a mile the author refuses to believe.

Rail and Airplane.

Following out this line of thought, and giving play to the imagination, experiment might be made upon the plan of a combination of rail and aeroplane—a semi-flying vehicle using both earth or rather rail and air as supporting and even propelling elements. There does not appear to be any existing example of such a means of locomotion at present, even in nature, unless it be the ostrich. Under such a system it is conceivable that the air-planes forming part of the vehicle would lift it very slightly off the rails, the driving power then being derived from the side wheels before mentioned, working against the side lines, which might take the form of thin bars or plates, so allowing for a small rise and fall of the vehicle. These and the other wheels would be rubber-tyred. A similar rail overhead might be necessary to keep the vehicle down, and thus the carriage would become a species of enclosed flying machine. Whilst such a plan might seem to involve contradictions it must, nevertheless, be recollected that the action of aeroplanes at great speeds of 100 or 200 miles an hour might reveal valuable conditions hitherto unknown. It might be found in practice that the vehicle would be kept constantly lifted off the bottom rails, and that the function of driving would be performed by the side and overhead wheels. Be it as it may, the matter is worthy of scientific investigation. If such a system were found practicable, the problem of mountain railways, among others, would be nearer solution. The monorail and the gyroscope might have their adaptations in such a scheme.

National Experiment.

If anything practical is to be accomplished without interminable waiting for the ordinary slow methods of first rendering improvements commercially paying, experiment must be carried out for the demonstration of any schemes or systems likely to prove useful. At present there are no opportunities for experiment. They would be too costly for the private individual or company. For example, in order to prove a new type of railway a stretch of land and considerable funds would be required. The

author ventures to suggest that a combination of our great railway companies, aided possibly by a grant from a Government development fund, might be made, and a right of way on Crown lands, or in such a place as Dartmoor or the Yorkshire moors, be secured and a staff of engineers retained for purposes of such experimental schemes. It is not too much to think that the cost would be covered by the discovery or development of something new and practicable. Hill-climbing methods, the effect of collisions, and so forth could be studied. Especially could the effect of very high rates of speed be studied. Part of the work might be that of giving scope to the ideas of poor inventors in a more generous spirit than at present exists. If we decided to "let Geordie have a try" now and then we might evolve a new Stephenson! At present we are too niggardly and unimaginative. Inventors seem to incur penalties rather than rewards under existing systems.

It is scarcely necessary to reiterate the importance of railways in the daily life of all civilised nations, especially in view of recent disorganisations. But it is time that engineers and general managers came to the rescue of society by devising means for safer, quicker and cheaper transport; and we believe that their ingenuity will not fail to keep pace with the requirements of this rapid age.

Discussion.

The Chairman proposed a vote of thanks to Mr. Enock for his paper, which certainly dealt with railway matters from the point of view of the idealist, but was, he thought, the more valuable for that very reason.

Engineers were always ready to discuss the practical details of their work, but they were not, as a rule, so ready to look at things from an absolutely outside standpoint. Mr. Enock looked at railway systems very much in the manner in which a visitor from another planet might look at them, and criticised without consideration of expediency or of what was likely to be immediately profitable. He had told them what engineers should strive for, and had endeavoured to start a practical discussion. Every pioneer had great difficulty in making people take his ideals seriously, and the higher the ideals the less likely were they to receive serious attention. Mr. Enock raised points which deserved the serious attention of railway engineers. It was profitable at times to review matters from such a standpoint as that adopted by the author, and the Society might very properly enter into such a discussion.

The average engineer was apt to treat comments such as the author had made with tolerant, self-satisfied amusement. There was even sometimes a feeling of antagonism against the person who had the hardihood to demonstrate that we were living in a

world which was still far from perfect, and that, hard as we had worked, we must aim yet higher if we wished to advance. Of course, it was not to be supposed that the author could deal practically with the matter in a short paper, but he had made a few suggestions in order to lead to discussion; neither was it likely that at a meeting like the present one the question of how we were to provide safer, quicker and cheaper railways would be settled, or that anyone would be able to point to anything which would lead to an immediate advance; but, on the other hand, it was to be hoped that a discussion would be started which would begin a new consideration of this subject.

There was no doubt that the higher the ideal the better would be the ultimate achievement; an ideal could not be too high. There was no doubt that at some future date many of the shortcomings pointed out in the paper would be set right, but they could only be set right by careful consideration and serious discussion. He (the Chairman) was not a railway engineer, and therefore, would not touch the practical side of the question. He hoped that there would be a good discussion of practical matters on the part of the railway engineers present.

The following communication from **Mr. F. G. Bloyd** (President) was read by the Secretary:—

I am pleased that during my year of office Mr. Enock has brought forward a paper dealing with the important question of railway construction and working, as not only is the subject one that appeals to me personally, but it is also one which should open out a thoroughly good discussion, seeing that the points covered are set forth broadly, and not in the highly technical manner usually found in papers read before a professional Society.

With the statement made by the author that "For all main "purposes of passenger and freight movement, the railway holds "its own," I am quite in accord, and although I disagree with his subsequent observation, that "the railway is still too slow, too costly and too insecure," and that "Either the limits of its capacity have been reached, or else engineers are displaying a lack of ingenuity in its development"—yet I would not ask for the entire deletion of the words, as the better side of a public service is often only discovered after it has first been soundly denounced.

It must be remembered that railway construction has from its inception been burdened by stringent and in some cases rather unfair legislation, and many desired improvements in working have been much curtailed owing to the narrowness of the gauge adopted by George Stephenson, and the restricted size of many of the large works planned by the earlier engineers.

Moreover, it must not be urged that present-day managers or engineers are lacking in ingenuity, or are blind to the need of

many improvements, for under modern conditions the hands of the best intentioned company are frequently tied owing to the exorbitant demands made by councils, local authorities or landowners, whenever any new works are proposed, and I would repeat the plea contained in the address that I had the honour of reading before the Society in February last, that until the regulations can be relaxed to meet the special circumstances that often obtain, and the more cordial assistance—not merely the sympathy—of local authorities and landowners can be enlisted, there will be but small inducement to companies to foster new schemes, or to capitalists to find money for them.

Railways must be regarded as public institutions, and with a more complete chain of co-operation between the Government, local authorities and the public themselves, on the one side, and the companies on the other, there should be little, if any, ground for doubt as to their future success in working.

Mr. W. M. Acworth said that he was not an engineer, and was only, in a very indirect way, a railway man. The Chairman had said that they could not pitch ideals too high. That was all right in theory, but he was not sure whether it was always profitable to attempt to translate that theory into practice.

This was the feeling that he had when he read Mr. Enock's proposal for carrying what might be called " collision buffers " on the train itself, in addition to having, as was frequently seen at big terminal stations, hydraulic buffers at the dead ends. He rather doubted, in the first place, whether the guards would consent to ride, as the author suggested, in the collapsible compartments prepared for their reception. Further, he did not think that the game was worth the candle. He did not know what the compartments would weigh with armour-plate and springs and so on, but it would mean a good many tons at each end of the train. Let them assume, for the sake of argument, that coal alone cost on an average 5d. a mile for a load of 200 tons. If they added 20 tons they would add a halfpenny a mile. They could do better with their halfpenny per train-mile, he thought, than spending it in reducing a risk that was really very small.

With regard to the next point, he had travelled a good many thousand miles on express engines in England and America. He used to think that the driver of a locomotive had a marvellously difficult job to perform. Since then he had travelled thousands of miles in a motor car, and it had impressed itself upon him that driving a locomotive was a mighty easy job. There was no steering to be done, and there were no animals to be avoided. The road was fenced. Locomotive drivers really had not anything to do except to look out for the signals. The time that it took to close the throttle and reverse the lever was only

momentary. He could not see what would be gained by their having another man in front, because he could not communicate instantly with the man who actually had the control of the throttle. Cost but not safety would be increased.

With regard to the list of accidents given on page 269 of the paper, he was bound to say that he thought that there was a question that engineers might look into. The number of failures of couplings was given as 2,440, and he wanted to ask engineers whether they did not think that it was about time that English railwaymen gave up playing with toy chains which they did their best to snap every time they started a goods train. He suggested that it was really time to couple trains in a less archaic manner.

As to collisions, the impression left on his mind after reading for many years the reports of the Board of Trade, was that they were nearly always the result of a combination of more than one cause, except where there was a sheer mistake on the part of an individual. Collisions happened where it was necessary that vehicles should be brought together. Mr. Enock spoke of a railway where there was to be nothing of that kind whatever; but surely it was going to have a terminus and was not going to run in a circle.

If they were to have single units running, as Mr. Enock suggested at the end of his paper, how were they going to carry anything like the traffic that a modern railway was expected to carry? On the underground railways, with an extraordinarily elaborate apparatus for signalling, they could get a procession of identical units all moving at the same speed at about $1\frac{1}{4}$ minutes apart. But if passengers were carried at a hundred miles an hour on the same rails with all the miscellaneous slow traffic, long intervals would be wanted between the units. If the passenger units consisted of a single coach they would never get a reasonable amount of traffic over the line. The only justification for a scheme of that kind would be the development of traffic to such an extent on a line, say, from London to Brighton, that they could afford to make a road which would carry one car every ten minutes or something of that kind, ignoring all intermediate points. But was it necessary to go in for such entirely new departures to get higher speed? What were the facts? On an existing railway in Germany trains were run at 120 miles an hour with electric power. At Brooklands a speed of 130 miles an hour had been attained with a motor. That could be done again to-morrow if they chose to put in the power. But they could not expect to do it with a steam engine under the normal conditions. The locomotive developed, perhaps, a thousand horse-power, hauling, say, 300 tons. They were using about 3 horse-power per ton; but an ordinary motor running on the road had something like 1 horse-power for each hundredweight instead of for six or seven hundred-

weight. A racing motor had anything up to 80 or 90 horse-power for a weight of, perhaps, 30 hundredweights, or 2 or 3 horse-power per hundredweight.

If they wanted speeds like that on the existing rails of to-day they could be got. But what were the speeds existing in practice at the present moment? Forty-three miles an hour was a commercial and not an engineering maximum. The fastest trains in the world have been running for more than ten years past from Philadelphia to Atlantic City. These trains are booked to do 55⅓ miles in 48 minutes. The company once ran this train special for himself and a party of English friends of his in 42½ minutes for the 55⅓ miles. No new system was wanted in order to get much better results if they could afford to pay for them.

On page 276 Mr. Enock dealt with the question of land, but he (Mr. Acworth) did not think that the comparison made was fair to English railways. He did not deny that the figures were correct, but they did not really represent the facts, because the single track miles excluded sidings.

In the Board of Trade returns each mile of single track of running line in England had, he thought, attached to it about half a mile of siding (speaking off the book). There were about 20,000 miles of siding, so that there were really about 50,000 miles of railway track in the United Kingdom. The corresponding figure for America was very much smaller. An addition of one-tenth to the running track mileage would probably represent all the sidings.

The typical thing that in England we called a railway was not the same as a railway in the United States. There the greater part of the area was very flat compared with England. The railway in the United States was made on the ground level; there were no bridges, no viaducts, and no tunnels. He had never seen figures on the point, but he was inclined to think that there were more miles of tunnel in England than in the United States. In England, the whole railway, being obliged to cross above or below the high roads, had to be made on an artificial level. The difference in the cost of construction on that account was enormous. Again, he once asked the engineer of one of the great English railways what was the cost of the platforms at an ordinary roadside station on a main line. From the figures given to him he came to the conclusion that such a platform, long enough to accommodate a main line train, cost about a thousand pounds. On the United States lines there were no platforms.

Then, too, the capital figures were not comparable, because the American figures did not represent cost. The President of the Pennsylvania line stated officially that his company had spent on the road in twenty-five years nearly £50,000,000 out of revenue. That process had been going on for the last ten years, on an enormous scale, in regard to nearly all the great companies. He

was quite sure that the figures at which American railways were now capitalised represented nothing like their actual cost.

He was sure that it was an error to believe that any large percentage of the cost of English railways was due to the cost of land. Capital expenditure nowadays was mainly on widenings, which clearly were made in the places where land was most expensive because they adjoined big main lines. And even there, as anyone could see who would examine the half-yearly accounts of the different companies, the cost of land was only a very small part of the total cost. The real cost was constructional cost. Nobody doubted that purchase of land had absorbed a larger part of the capital in England than it had in America. When railways were made in Chicago they were put down in a field, and the town grew round them ; but when the Great Central came to London a few years ago, hundreds of houses had to be pulled down. He expected that every engineer agreed that the cost of English railways was higher than it should be, because every engineer who had had experience of getting railway Bills through Parliament knew how much the cost of construction was increased by the demand that railway companies should spend a sovereign in order to do half-a-crown's worth of good to somebody. Parliament was very tender about alleged inconvenience to private individuals. And local authorities were even greater offenders. Parliament imposed expenditure out of all proportion to the benefits that were obtained by the people who asked for them.

He would ask Mr. Enock to notice one thing which arose from his saying that fruit rotted on the ground because the cost of transport was prohibitive. He (Mr. Acworth) ventured to suggest that if anybody would look into the facts as to how the difference in cost between the original producer and the ultimate consumer was made up, he would find, no matter where the goods came from, that the bulk of the cost was not made up of transportation cost, but of distribution cost. He had often wondered why nobody took up that question. He was sure that, when they came to look into it, they would find that the actual railway cost was very often quite the smallest part of the difference between what the producer got and what the consumer paid.

Mr. Ernest Benedict said that, although the paper contained many statements with which he could not agree, the author had shown proof of great enthusiasm in his ideals ; these, from his (Mr. Benedict's) personal experience, had been the ideals of engineers ever since he had known railways. The true engineer tried to do the best for his employers, to work as cheaply and as quickly as he possibly could, and to make everything of the best so that railway travelling should be as safe as possible ; while at the same time bringing his labourers along with him. The old-

fashioned school of engineers looked upon the men that helped them as men and—if he might put it so strongly—as brothers. He was afraid that that feeling had much weakened, but it ought to be encouraged, and the labourers should be taught that it was to their advantage to give the best work at all times instead of doing as little as they could for their wages. He was, however, afraid that that result could only be attained under present conditions by a system of co-operation. A workman's pride in his work for the sake of the work was almost a thing of the past ; failing this, the labouring man must get something out of the work financially or he would not improve his output.

The author had made many suggestions for increasing the speed, the security, and the economy of railway working. But every one of these increased the cost of the railways ; and, in his (Mr. Benedict's) opinion, the only way in which some economy could be effected on the railways as they were was by getting better work out of the men. The principal means for bringing about great economies was very much more simple and effective than anything suggested in the paper. It was by inducing the public, Parliament, local authorities, and everyone else, as well as the labourers, to abandon that vicious groove in which they had been moving from the beginning, and no longer to regard railway companies as milch cows, for all these classes have always tried to get as much as they could out of the railways. If that state of things could be stopped, and if the railway companies could be relieved of the enormous rates and taxes which they had to pay and of the luxurious accommodation upon which now-a-days everybody insisted, a useful amount of saving would ensue. He could look back to a time before the majority of those in the room were born. The accommodation demanded in these days was very different from what it was when he first travelled down to Plymouth with Mr. Brunel in the year 1848. Then luggage was piled on the tops of the carriages, and the third-class passengers were carried in what we should now call cattle trucks. There were no Pullman refreshment and sleeping cars sixty or seventy years ago.

The author proposed to increase the safety of railway carriages by making them heavier. That, of course, involved cost. If these and other greater traffic facilities were wanted they must add to the number of their lines, and where there were now two lines they ought to be in a position to lay down three, four or five parallel lines. Then more trains or faster trains might be run. This could be done for less money than in procuring land and wayleaves and constructing a special line and rolling stock on Mr. Enock's plan. However, it was impossible nowadays to raise capital for any such purposes under any practical terms, in consequence of the obstructions put in the way of railway companies, to which he had alluded.

The author had proposed that the land for railways should be given by the Government, an excellent but rather belated recommendation as regards England. The Government of India had always made a free grant of any land required. If the Government in England wanted to do anything for railways they could do it in the way that he had pointed out.

With regard to accidents to employees, was it not well known to everybody that had anything to do with railways that, almost invariably, the accidents arose from the men's own carelessness? "Familiarity breeds contempt." A man would work on the lines and forget the danger, and while he was intent on what he was doing he would get run over. Such things could not be helped. They could not cause every regulation on a railway to be properly carried out; some risk must be taken.

He quite agreed with Mr. Acworth that it would be of no use to put another man in front of the engine. What would the poor man do if he was travelling at 60 miles an hour in a snowstorm and could not see anything at all? He would not be able to use the binoculars in such circumstances; and, if he was put in a cabin in front, he would probably go to sleep. He did not think that it would be possible to adopt the author's suggestion, which, moreover, would involve additional cost.

Then there was the question of attention. Train hands should always keep a keen look-out, but he was afraid that some of them thought that they could risk taking little naps occasionally. That engine driving, as Mr. Acworth said, was a comparatively easy job is proved by the fact that the natives in India drove their engines just as well as did white men elsewhere. They were not put on passenger trains simply because there was a feeling among Europeans that they did not like to trust a native with such a task. But all goods trains in India were driven by natives, mostly Parsis.

With regard to the buffer carriage which the author proposed to put between the engine and the train, what was to become of the engine in a collision? That was rather a dangerous thing to have in front of you. He was afraid that the buffer would be fatal not only to the engine driver, but to the guard, as Mr. Acworth had pointed out, and such a carriage would be an additional expense to build and to work.

Mr. R. J. Simpson referred to the statement made by the author, on the first page of the paper, that the world's railways were still killing and maiming large numbers of people. On the second page the author gave a table showing the number of killed and injured on the railways in the United Kingdom and the United States; but it seemed to him (Mr. Simpson) that the table was hardly fair to the railway companies, and that it was apt to give a wrong impression; for, if the table was looked into,

it would be seen that the statistics were not nearly as bad as appeared at first sight. The author himself said, lower down, that, taking the number of passengers killed in the United Kingdom, only 18 of the 125 were killed owing to accidents on the railway. According to the Board of Trade reports, the remainder or most of the remainder were killed through their own stupidity either in attempting to get into or out of trains in motion, or by accidents due to their own carelessness. Practically the same remark applied to those who were injured. Out of the total of 3,502 only 534 were injured owing to what might properly be called a train accident.

With regard to employees, the far greater number of those killed and injured suffered through their own fault. A reference to the report of the Board of Trade enquiries into those accidents would show that fact. Notwithstanding the rules and regulations which were made for the men's safety, the men would persist in ignoring them. No doubt the large number of casualties in the United States was due to what the author called the spirit of independence in the American character.

Under the heading of "other persons," the author had given the figure of 577 killed in the United Kingdom. Before coming to the meeting he (Mr. Simpson) referred to the Board of Trade reports for the first six months of 1907, and he there found that in that period 226 of the persons killed were trespassers or suicides. He thought that few people realised how very popular a railway was for would-be suicides. It seemed hardly fair to include them in the number of those killed on the railway. It was not in any way the fault of the working of the railway that all those 577 persons were killed and that 959 were injured.

It also struck him that it would be fairer if Mr. Enock had shown a comparative statement beginning, say, thirty years back. He found that in 1880 the proportion of killed was 1 in 21,000,000; in 1890 that was reduced to 1 in 45,500,000; in 1900 it was 1 in 71,250,000; in 1909 the number was still further reduced to 1 in 126,000,000. This was the case notwithstanding the tremendous increase in the train-miles run. He thought that those figures would prove conclusively that engineers did not lack ingenuity in the development and in the working of railways.

With regard to the patent buffer which Mr. Enock suggested, it would appear that the one which he proposed to put in the centre of the train would, of course, do away entirely with the corridor. The author did not show any method of having a corridor in a train with such a buffer.

Major Hurlstone Hardy said that he agreed entirely with what the President had said in the communication which had been read to the meeting. He would say, in addition, that, England being so densely populated and commerce and travelling

being so generally provided for, railway engineers were tied to the present system. In some other countries and in other circumstances there was a possibility of introducing novel methods, but British railways were practically tied to the development of existing methods, and were also tied with regard to expenditure. Moreover, there had been a great rise in the price of material and labour and in the demands which were made by the public. All these things tended to increase expenses, whilst the commerce of the country demanded cheaper transport for goods, and particularly for food. The produce of British growth competing with imports from the Colonies would in future suffer heavily if English railways could not keep down traffic charges.

With regard to new light overhead railways and schemes of that kind, he thought that the only possibility of development in that direction was that they could be developed experimentally in England prior to their application abroad in places where the ordinary railway could not for the present be economical.

There was a point to be considered in relation to economy. Up to the present time railways had had portions of the country allotted to them by Parliament for their sole occupation, but these areas were now being encroached upon by motor traffic. The railway companies at first had the traffic of a district with a certain amount of naturally limited competition between rival lines, but they were not then exposed to the competition of heavy goods motor traffic, which broke down public roads repairable out of the local rates. Such competition was unfair to the incorporated railway companies, and if it was allowed to a very large extent would deprive the railways of part of their fair profit in the future on the increasing income from carriage of goods and people. There was, as one might say, a contract which was supposed to be tacitly set up, when a railway was created by Act of Parliament, that the railway should have the heavy traffic of its district. But now that privilege was being taken away from them. The tramways, no doubt, properly competed for a great deal of suburban passenger traffic. The railways must pay a fair dividend, but with increasingly heavy expenses they would certainly be unable to conduct the public business as cheaply as formerly if they were to be deprived of what was their fair inheritance.

As to the idea of a light railway, which he would call a light aerial railroad, there was he thought a possibility of that kind of thing being introduced in undeveloped countries, but in a very different way from that which the author had sketched.

In this connection he was greatly struck with the possibility of effective propulsion when the author referred to what could be done in aeroplanes and what could be done in motor cars. When the screw was first proposed for marine propulsion he thought that the credit was not given to the proper party. Professor Benet Woodcroft, F.R.S., with whom he served for some years,

had never had adequate credit for proposing the screw propeller in marine propulsion. The form of the marine screw propeller had been too closely copied by aeronauts. A radical difference of form was required when working in a dense and non-elastic medium and when flying in air. He felt sure that the screw propeller had possibilities of efficiency in driving power in an elastic medium which had not yet been reailsed. In fact, he knew that the aeroplane propeller was about to be made very much more effective than it was at present. He had ridden in light railroad inspection cars, and contemplated the construction of stronger and still lighter cars. Now, if they were to have a motor car so light that it could ride on a cheaply built aerial railroad, they might swiftly and safely cross the deserts of Egypt and other such places; but this was not suitable for England. The details of the development might thus be very different from what the author outlined. That was quite a distinct subject from the development of mono-rail and the like in England at the present time. The paper contemplated too great changes, which were impracticable in a densely populated country like England.

Mr. S. A. Stevens said that he, like Mr. Acworth, felt that he owed an apology to the meeting for trespassing on its time, as he was not a railway engineer. On page 269 the author spoke about accidents to shunters due to coupling and uncoupling. That subject had been considered by managers and engineers of railways for years, and despite innumerable attempts and experiments, they had yet to find a coupling which would be automatic and, at the same time, interchangeable with the existing coupling.

On page 270 the author said that carriages were not built to stand collision. He (Mr. Stevens) emphatically differed from him on that point. In his early days he was connected with a railway. He knew that in breaking up a carriage which had been in use for over 20 years on the much maligned Chatham and Dover Railway, sledge hammers had to be used because the carriages were so well built. He thought that modern railway carriages were models of construction for the purposes for which they were intended.

The paper throughout its whole length dealt almost entirely with passenger traffic, and goods traffic was left to take care of itself. Mr. Acworth had said that the cost of the carriage of goods was a very small item of expense to the consumer, but he did not agree with him. Over seven million tons of coal came to London in the year, the main portion of which was from Nottinghamshire, Derbyshire, Leicestershire, and Warwickshire. The average cost of the coal at the pit was 8s. to 9s. The average cost of the rail carriage was almost the same figure.

Mr. Acworth, interposing, said that the cost to the consumer had just about as much again added to it to get it from St. Pancras, say, into the consumer's cellar. That was an extreme instance, but he was not talking of coal.

Mr. S. A. Stevens, continuing, said that all the same he could not agree with Mr. Acworth in any way. He wished to emphasise the need for cheaper transit.

A point that he wanted to make very strongly was that nothing was said in the paper about the improvement of goods traffic. If goods trains could be run at 60 miles an hour, if there were improved methods of dealing with goods trains, lines would be very much less occupied by them than they were at the present time, and as a consequence travel would be enormously facilitated and quickened.

The question of signalling was another point. The present system in England had grown out of numberless Board of Trade regulations. It was safe beyond doubt, but it was equally beyond doubt that, if only a system of automatic signalling were brought in, it would save an enormous amount of time.

Another point was that the present road locomotive, whether a bicycle or motor car, had ball bearings. Sir George Gibb tried a system of ball bearings on the North-Eastern Railway, but it was not altogether satisfactory. With such bearings a train would want less tractive power to haul the same weight, and could travel much faster and at less cost.

He thought that the author, in his table of certain train speeds, was very unfair to railways in England. He put the slowest journey between London and Plymouth as eight hours, but it must be remembered that trains must stop at certain places, however much it was desired to fly across the country. A train such as that was not intended to get from one end of its journey to the other in quick time.

Mr. E. Kilburn Scott said that labour unrest on railways, although regrettable in many ways, had a bright side to it, and that was that it was likely to give opportunities to inventors and engineers. There was more likelihood of improvements in machinery, etc.,being adopted when there was trouble with labour, than when labour was quiet.

In the paper the author mentioned that a line was wanted in this country where railway experiments could be carried on, which experiments should be financed by the companies alone or with help from the Government. That was exactly what occurred on the Zossen line near Berlin, where two electrical companies and a company making rolling-stock joined with the Government in a syndicate to study and test high-speed traction problems. The railway line used was a strategic and not a commercial line, and so the experiments could be carried on

without interference from ordinary traffic. We need not go to the Yorkshire moors for a place for an experimental line ; there were plenty of places in the South of England (Kent or Surrey) near the Continent where a strategic railway would be useful ; that is to say it could be placed where it would not carry much traffic in the ordinary way, but it would be there in case of war. Germany did a very great deal for the engineering world in publishing the results obtained on the Zossen line. The German Government and the firms who financed the experiment are very much to be commended for it.

The high figures for coupling accidents staggered him, and it was high time something was done to reduce them. He had an idea that, on electric railways at any rate, electric current might be utilised in connection with the coupling. He did not see how carriages could possibly be coupled together with an electro-magnet although the electro-magnets were doing wonderful things in crane work ; even locomotives could be lifted by them. Possibly there might be an opening for electricity to operate a catch for the coupling hook.

He wondered why somebody had not raised the point of the nationalisation of railways during the discussion, as the paper seemed to call for a remark on that point. He used to live on the South-Eastern line, and when a train was stopped on one of the bridges, or came in late, the remark was commonly made, " I wish that railway lines were nationalised." His experience of nationalisation was such that he did not want to live in a country whose railways were nationalised. Four years' experience of nationalised railways in Australia had brought him to the conclusion that, instead of being a nation of grumblers at railways, the people living in Great Britain ought to be very pleased indeed with the fine services that they were given by the companies. His distinct opinion was that with regard to railways we were the best served people in the world, and we were certainly very much in advance of countries where the lines were State-owned.

Mr. A. S. E. Ackermann said that he would like the author in his reply to reduce the statistics relating to the killed and injured to killed and injured (respectively) per train-mile and per passenger-mile, as he thought that there was some unfairness to America in the way the facts were stated, e.g., in the United States the single-track mileage was, according to Mr. Enock, six times that of the railways of England. Multiplying the English figures by six immediately reduced the apparent discrepancy between the two countries. Probably the rates per train-mile would give another aspect to the case.

He took it that the figure of 1 in 83 millions, the last paragraph but one on page 268, referred to England. The author might add the corresponding figure for America if he had it.

He would like to know how the steel coaches which were used so much in America behaved in railway accidents. There they apparently had plenty of experience of railway accidents, and consequently it ought not to be difficult to get particulars as to how the carriages behaved in a collision.

Mr. E. W. Chalmers Kearney wrote: The subject of Mr. Enock's paper is of peculiar interest to me, as I have devoted my life to the problem of high-speed transit. I did not start out as an inventor with an idea to exploit, but merely with the conviction that something had to be done to improve the present means of transit, and with my mind entirely free as to the best means to adopt. For the first four years (1902-6) I did nothing but research work, examining during that period every system—and the number was very large—that claimed high speed as a characteristic. I found none that I considered practicable, and it was only then that I determined to design a system myself. Armed with the wealth of information on the subject which I had gleaned by research, it did not take long to decide upon the broad features of the system which is now known as the Kearney High-Speed Railway. From 1906 to the present time has been devoted to experimental work and to the gradual improvement of the system in detail, and I can now fairly claim to be in a position to design and supply a railway capable of maintaining the high velocities forecasted in the paper. In England, however, inventors and promoters of new ideas are looked at askance, and every possible difficulty is thrust in their way. One has to suffer much through misrepresentation and even personal abuse.

On several occasions public demonstrations of my models have been rendered futile by deliberate mutilation—electric wires have been cut, rails removed or bent, and once the whole of the supports to one of the stations were sawn through!

What I regard as essentials in any high-speed railway system likely to prove a commercial success may be tabulated as follows:

1. Absolute safety from derailment.
2. Economy in construction.
3. Simplicity, especially at junctions.
4. Low working costs at high speeds.

In the Kearney High-Speed Railway the first essential is met by the provision of a single bearing rail, which eliminates lateral oscillation, in combination with a single overhead guide rail. The carriages are held securely in position between the two by specially grooved wheels and clips which permit the cars to run freely at all speeds. No derailment can take place unless there is an actual rupture in the permanent way. It should be borne in mind that with a single bearing rail employed most of the factors are absent which commonly tend towards disaster.

The second essential is met by utilising the guide rails of the up and down tracks for mutual support by means of cross bracing. In effect this gives a lattice girder 13ft. deep, which permits of the necessary strength being obtained with the employment of a very small amount of metal. As now designed the superstructure of the Kearney High-Speed Railway will take a side load per car length of over 7 tons with a factor of safety of $2\frac{1}{2}$. As the side pressure is never likely to exceed $2\frac{1}{2}$ tons per car, the actual factor of safety is over 6, which compares very well with the accepted factor of safety of 1.7 for ordinary railways. Comparing the actual cost of a double track—permanent way only—of twin-rail and Kearney systems, the latter will show a slight advantage only, but if the difference in grading required and saving on route mileage is considered an economy of from 50 per cent. to 60 per cent. can nearly always be shown by the use of the Kearney system.

The third essential of simple construction is well met in the method I propose, and the ease with which switching operations can be carried out at junctions is a characteristic of the system. Most inventors of high-speed railways, I find, seem to ignore the necessity and fail to make provision for junctions, but one or two have gone further, and actually put forward this serious disability inherent to their respective systems as an advantage !

The fourth essential is covered by paying careful attention to the shape and exterior surfaces of the carriages, with a view to minimising air resistance, which increasing by the square of the speed, soon becomes the largest factor affecting the output of power. The use of ball bearings, which I find are quite satisfactory on vehicles running on a single rail, will also play their part in a lesser degree. Rolling resistance is so unimportant compared with air resistance at high speeds that I am of opinion that ball bearings will be used not so much for the sake of the power they will save as their freedom from liability to heat up. I calculate that a Kearney High-Speed car of 20 tons could maintain a speed on the level in still air of 120 miles per hour with an output of 269 h.p., of which 250 h.p. would be used in overcoming air resistance.

The above would seem to clash with the author's proposal for a "Rail-Airplane." It is almost certain, in the face of the high value of air resistance, that the planes would consume more power than they saved by reason of any lightening of the weight on the wheels. Against this must be set the advantage gained by reducing the wear and tear of the permanent way, but there would certainly have to be a limit to the "lift," as, even with a motor fitted to every other wheel of a train, half the weight of the train is required to give the necessary adhesion for tractive purposes at 200 miles per hour. I do not think there would be any advantage in transferring the pressure required to the overhead

rail, even if this did not present a difficulty in designing the overhead structure to withstand it.

With regard to the author's suggestions regarding cross-country overhead railways I fear the lightest that could be erected with due regard for safety would greatly exceed in cost that for a surface line including land. The Liverpool Overhead Railway cost £90,000 per mile, and even the comparatively light structure required for the Kearney High-Speed Railway, where the whole weight of the train can be concentrated on a single plate girder, the cost would run to nearly £50,000 per mile.

In connection with mountain railways it is interesting to note that, with an electric train with a motor on each axle, the present maximum gradient of 1 in 20 can be increased to 1 in 6½. Further, as rise and fall affect speed inversely as the speed, high-speed trains will have the additional advantage of being able to " rush " a mountain side set at any angle that passengers will face—e.g., a train travelling at 200 m.p.h. could negotiate a gradient of 1 in 2½ (say) and climb to a height of 1,000 feet, and still be running at 100 m.p.h. at the top, this solely by virtue of its own kinetic energy.

The velocity head of a train at			30	m.p.h. is about		30 feet.
,,	,,	,,	60	,,	,,	120 ,,
,,	,,	,,	100	,,	,,	332 ,,
,,	,,	,,	120	,,	,,	480 ,,
,,	,,	,,	150	,,	,,	752 ,,
,,	,,	,,	200	,,	,,	1,328 ,,

The natural law at work here is a fortunate one for the future of high-speed railways, while it accounts for the great variation between maximum, minimum and average speeds characteristic of our present railways. A train at 60 m.p.h. encountering a sudden rise of 120 feet is brought to a standstill, supposing its power to have been cut off at the foot of the gradient, while if a train at 120 m.p.h. is similarly treated the effect is merely to reduce the speed at the top of the hill to 100 m.p.h.

The Author, in reply, said that he was glad to have aroused so much discussion, although he might have wished that the criticism had been more constructive and less destructive. Possibly destructive criticism was inevitable in view of the character of the subject, and the customary tendency to attack new ideas. He thanked the Chairman for his remarks about idealism, because the paper was of course written partly from that point of view. He believed that imagination must precede a good deal of what engineers had to do, just as it had preceded great movements in the past. As an example, they would recollect that America was discovered by the imagination of Columbus, aided by the cash obtained from the jewels of Queen Isabella.

He was pleased to hear the President's letter read, and regretted that that gentleman, as an authority on railway matters, had been unable to be present.

It had been said by Mr. Acworth that the guard might object to riding in the proposed buffer carriage. There was no doubt that the guard objected even at the present to being smashed up in his own private compartment in the front of the train, which happened occasionally, but the proposed carriage would protect him. As to the weight of the buffer carriage, that was an item to be considered, of course ; but it must be recollected that there were often three, four or more empty coaches in trains, which were practically dead weight, possibly because there were not enough passengers to fill the train, but also because, as he said in the paper, passengers distrusted the front coaches. The buffer coach was rather to replace those empty coaches.

As regarded a special man on the look-out, that was only a suggestion, but he thought that the criticism which had been directed to it had not taken its possibilities into account. Mr. Acworth had said that the man on the look-out would not be able to communicate with the engine driver—for example—in a snowstorm, but most of those present, doubtless, had travelled on ocean steamers, possibly in snowstorms and gales, and they knew that the man on the look-out had no difficulty in communicating with the proper official in emergencies.

Another point made by Mr. Acworth was in regard to specially quick trains in the United States, and he had given instances of some very rapid journeys. Of course those abnormal speeds could be reached, but lives were risked in doing it, and that was what he thought they should endeavour to obviate in a new type of construction.

As to the matter of land, the figures which he (the Author) had given for single-track mileage were taken from the Encyclopædia Britannica. They were there, put in the way in which he had given them. Possibly they were capable of some modification, but with regard to the relative cost of construction in the United Kingdom and the United States, the cost of the best railways in the latter country was given at practically the same figure as the cost of construction in England, without the land. There was therefore no doubt that the cost of land in England had to a large extent—if not quite so much as appeared—figured in the greater cost of English railways, and in the interest of the community this cost ought to be lowered in the future.

Co-operation had been referred to by Mr. Benedict as a probable remedy for the labour difficulties that had been witnessed. Although that was not a point which greatly concerned engineers, it was, nevertheless, inseparable from the present subject ; and, for his part, he believed that co-operation or profit-

sharing would furnish the solution of the difficulties, not only in railways, but in other industrial matters. He believed that the ideal relations of master and servant, however much it might be regretted, belonged to the past; and that the labourer was now beginning to think that he was worthy of a better hire. Society was turning over very greatly, and it was absolutely useless to close their eyes to the fact.

The matter was also touched upon by Mr. Kilburn Scott when he spoke of the nationalisation of railways. No suggestion had been made in the paper that railways should be nationalised. He (the author) had not gone into that aspect of the subject very much, but he did not think that he should advocate it. In some countries he had visited, where many of the railways were owned by the Government, they were badly served. The danger of railway nationalisation, it seemed to him, would be that railways would tend to become machines for political and other favourites, and nepotism generally, and under such conditions they would not give an efficient service. Rather than nationalisation he would suggest co-operation and profit-sharing.

Complaint had been made by Major Hardy of the unfair competition of electric trams and motor traffic with railways, but were the railways doing their utmost to compete? The fault might not be theirs, but it might be the fault of a moribund system. Those who had followed the discussion in the Press lately, which had been brought about by railway strikes and so on, would have seen indictments made against railway management in an economic sense. He had with him a cutting from an article in the *Fvening News* of September 19th, 1911, which periodical could not be accused of being a Socialist or anti-capitalist paper, in which there was an indictment of the wasteful methods employed, especially in the handling of goods traffic.

The same speaker had said that the system of light overhead railways, such as the paper suggested, were not suitable for England, but might be useful for Egyptian deserts. But why? If they were practical in an undeveloped country why were they not so in a developed country, and even more so where the value of land was considerable and still growing?

It had been said by Mr. Stevens that there was no mention in the paper of goods traffic. He (the author) had not gone very much into that question for he was mainly occupied with a quicker and more economic conduct of the passenger traffic; but he did not neglect the goods traffic altogether, and he believed that the principle which he advocated of swift individual vehicles even for freight traffic was feasible and advisable. They saw how easily goods were carried in steam lorries in the streets, and that, he thought, gave an example of the possibility of handling goods in that way on the railway. This, of course, was to be taken in conjunction with what had been said in the paper about

new types of railways, to overcome heavy gradients, especially in mountainous regions.

With regard to the question of speeds, of course the averages included the slower trains, and his idea was to show the general times of travel, and that, in his opinion, travel was too slow.

He did not, in his paper, make much mention of the mono-rail. He simply put in a sentence, which he had not read to the meeting, saying that it might have some adaptation or development. He really knew very little of the mono-rail, and when he had heard first of it he did not greatly believe in its commercial practicability.

Complaint had been made by some speakers of Parliamentary and municipal restrictions and regulations, and the heavy rates, and so forth, against which railways had to contend. It was a fact that railways seemed to labour under these burdens, but he thought that it was part of the duty of the engineer to create, or to help to create new systems which would give the Government and people confidence, and which would enable burdensome regulations to be removed, and bring about cheaper and better methods of travel which in time would supersede the old ones.

He must stick to his colours in regard to what he had said about scope for imagination and experiment in the matter of railway science. He believed that it would be advisable to bring about some national experiments, and that idea was supported by one speaker. He maintained that there was room in railway engineering work for greater ingenuity and new methods.

The author also communicated the following supplementary remarks :—

I have received a number of Press cuttings reporting the lecture and various letters from private individuals showing the matter to be of public as well as technical interest. In the *Evening News* article referred to in my reply, which deals primarily with Mr. Gattie's scheme for a central clearing-house for goods in London, the writer points out that there is at present enormous and unjustifiable waste in our transport system, and that if that waste were checked by the adoption of some such scheme as Mr. Gattie's the companies would be enabled to pay their men more, simply because, under improved conditions, that abour would be worth more. The article in many respects supports the arguments I advanced for more scientific management. Of course, the managers may have something to say for themselves. I would, however, once more draw attention to the matter of half-empty passenger trains, and ask if single motor carriages, run at the slack hours of the day, would not at least economise fuel. There was no reply to this point in the discussion. A few weeks ago I journeyed to Portsmouth from Waterloo by a mid-day train. This train was of great length, but

there was no passenger except myself in the compartment I occupied, and I particularly noted many coaches without passengers at all. Do railway shareholders care nothing about the consumption of coal, to say nothing of useless wear and tear upon rolling stock and permanent way?

In my opinion—pending estimates I am having made—the cost of light overhead railways would be less than that of the present system, which is also too cumbersome, and I believe that light overhead lines, such as advocated in my paper, would give a great impulse to travel, and that these lines could be constructed at half or less than half the present cost. It does not necessarily follow that existing systems would be relegated to the scrap-heap.

6th November, 1911.

H. C. H. SHENTON, Vice-President,

in the Chair.

TWO-STROKE CYCLE ENGINES.

By Robert W. A. Brewer, A.M.Inst.C.E., M.I.Mech.E., M.I.A.E.

[fellow.]

The enormous development in mechanical transport which has taken place during the last few years has been achieved by a gradual perfecting of the internal combustion engine, with the development of which the name of Mr. Dugald Clerk stands out prominently as being that of probably the most persistent and scientific investigator on problems connected with this type of engine; a type which, practically speaking, has ousted all other movers, whether they be primary, such as the steam engine and boiler, or secondary as the accumulator and electric motor.

Internal combustion engines may, roughly, be divided into two classes, namely, those working on the two-stroke cycle and those working on the four-stroke (or Otto) cycle, the former of which Mr. Clerk has been investigating since 1877, his first practical and complete engine being exhibited at the Kilburn Exhibition of the Royal Agricultural Society in 1879. In this engine there were two cylinders whose pistons were connected to a shaft having two cranks. One of the cylinders took in a mixture of gas and air and compressed it into a chamber at the back of the working cylinder. From this chamber the working cylinder received its charge through a slide valve, which also acted as an ignition valve, ignition being effected by an incandescent cage of platinum kept in a heated state by the successive explosions. This was the first explosion compression engine to give an impulse at every revolution. The first cylinder was used as a pump to deliver the mixture into the reservoir at a pressure of about 70 lb. per square inch.

In this engine Mr. Dugald Clerk sought to combine the advantages of compression before ignition with the complete expulsion of the exhaust gases, by reducing the clearance at the back of the cylinder to a minimum. However, great difficulties were met with in this, the first successful engine working on the two-stroke system, the chief of which were back ignition in the compression reservoir, and excessive shock in the motor cylinder. The latter difficulty was eventually minimised by modifying the shape of the combustion chamber, but the former was never overcome.

In 1880 an improved Clerk engine was built. This had a conical combustion chamber into which the charge was pumped through a mushroom valve, the exhaust taking place through

annular ports in the cylinder walls when the piston was at a crank angle of 40° before the outer dead centre. The pumping was carried out by means of a separate crank set at an angle of 90° to the main working crank. In this way the explosive mixture of air and gas in the pumping cylinder underwent a slight compression during the firing stroke of the previous charge in the working cylinder. After the exhaust ports were uncovered and the pressure in the cylinder reduced below that in the receiver

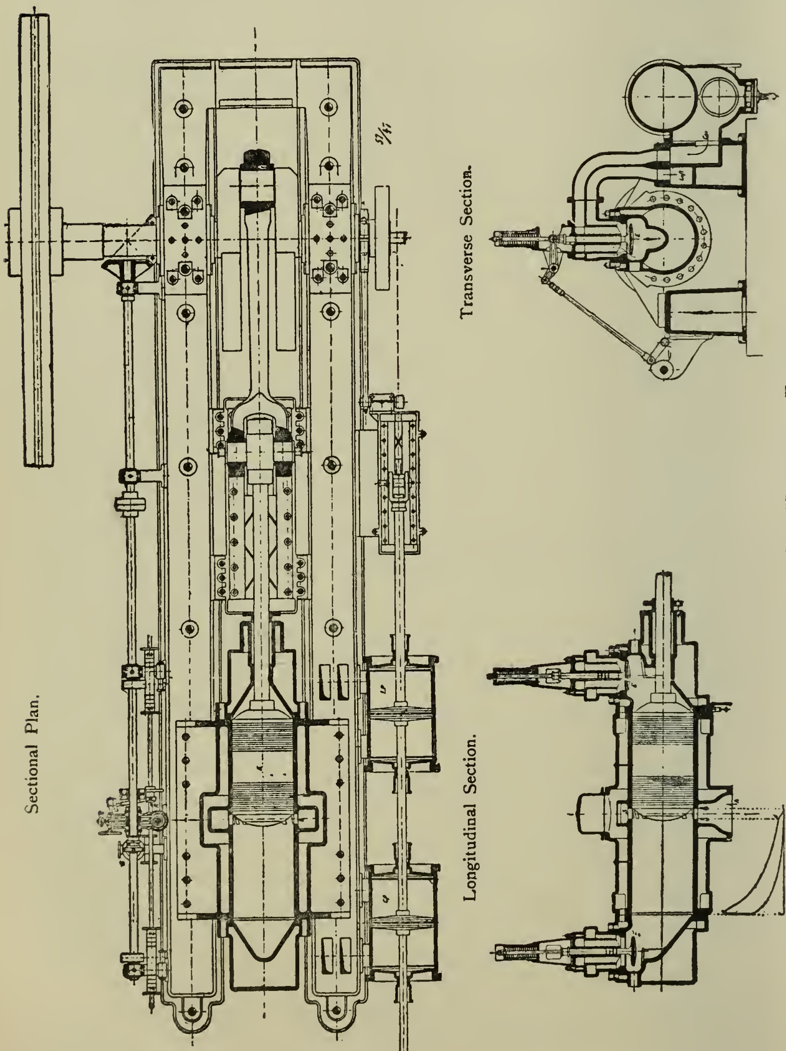


Fig. 1. -The Koerting Engine.

the fresh mixture passed automatically into the working cylinder. The final compression was carried out by the working piston on its return stroke.

Messrs. Koerting Bros. have for some time built large engines on the Clerk principle, but in these large modern engines it is only possible to obtain economical working, while avoiding the risk of firing the incoming mixture, by supplying the air and gas through separate pumps. The Koerting engine unit consists of a double-acting power cylinder fitted with a double-acting air-pump and a double-acting gas pump, these two being in line with each other and on the same piston rod. In a double-acting engine a most important relation exists between the length of the piston, the stroke, and the exhaust ports, which are placed annularly round the cylinder. The piston must be of such a length that these annular ports are not overrun more than is necessary for their complete uncovering, and the piston must therefore be of a length less than the stroke by an amount equal to the width of the exhaust port.

Large two-cycle gas engines are almost invariably used in connection with a fuel of low calorific value such as producer or blast-furnace gas, whose value is of the order of 100 to 150 British thermal units per cubic foot. This quality of gas is difficult to obtain free from dust and traces of tarry matter ; for this reason successful working can only be obtained when efficient scavenging takes place. In an engine of the type under consideration,where two separate pumps form essential details of the design, scavenging can be carried out in a simple manner by arranging the distribution valves so that the blast of air precedes the charge of gas at the end of each stroke. It will be necessary to bear in mind this important point in two-cycle work, because one of the great difficulties to be encountered in running engines under variations of load and with different proportions of mixture or attenuations of charge to meet such conditions, is to keep the engine working on the two-stroke and not on the four-stroke system. This peculiarity of the two-stroke engine will be referred to later on.

The two-cycle engine should have the following advantages over the four-cycle engine for large powers :—First, the working volume of the power cylinder for a given output should be one-half of that required for a four-cycle engine at the same speed ; second, in a two-cycle engine design the exhaust valves should be eliminated. These, in large engines, are a source of some anxiety on account of the power required to lift them, and the excessive heating to which they are subjected. Thirdly, weight for weight, a two-cycle engine should be considerably more powerful than a four-cycle engine, or conversely an engine of equal power can be much lighter when working on the two-stroke principle ; and, fourthly, the working pressures in a two-cycle engine can generally be lower than in a four-cycle engine.

In the larger powers numerous mechanical difficulties are met with, as in the construction of very large pistons in single units and from the fact that a limiting value of dimensions has been almost reached under the prevailing conditions of working and materials obtainable. As this paper is intended to deal with small high-speed types of two-cycle engines one may be tempted to think that the conditions prevailing in large engine practice were of little interest to the automobile engineer. However, what has already proved a practical system on a large scale is daily becoming more appreciated for smaller powers.

The two-cycle engine has been manufactured to a considerable extent in America, principally for use in motor boats, but there is no reason why it should not take the place in motor car work which this type of engine might be expected to occupy on account of the possibilities of weight reduction and power increase theoretically attributable to it.

Two-cycle and Four-cycle Engines Contrasted.

To some it may seem futile to consider at all the possibility of supplanting the Otto cycle engine—even to a limited extent—by the two-cycle engine. During the past twenty years the attention of engineers has been concentrated upon the Otto cycle, and it is therefore only to be expected that this type of engine should be in a state of practical perfection after so much thought and labour have been expended upon it. On the other hand, the two-cycle engine problem has been tackled by comparatively few, but there are now several very excellent two-cycle engines doing regular work with economy.

The two-cycle engine problem is a very difficult one, and in he past the following have been the principal defects, viz. :—

(*a*) The difficulty of controlling the speed and the power.

(*b*) The loss of unburnt charges down the exhaust pipe.

(*c*) The variation in the composition of the mixture due to attenuated charges and misfiring.

(*d*) The difficulty of *entirely* displacing the burnt gas from the cylinder, and filling it with a new charge ; and

(*e*) The excessive fuel consumption.

Considering first the most difficult problem, namely, that of dispersing the products of combustion by a complete cylinder-full of fresh mixture. If this operation can be effected, the power obtained from any one cylinder working on the two-stroke principle should be theoretically more than double that obtained from the same cylinder on the four-stroke principle, the proportionate increase of power being represented by the ratio of the compression volume to the total working volume. Clearly this should be the case, as in a completely scavenged cylinder the compression volume, as well as the working volume, will be filled with an explosive mixture.

By comparing the losses in a two-cycle and a four-cycle engine and investigating their causes, we can endeavour to come to some conclusion as to whether a small two-cycle engine can be reasonably expected to compete with a four-cycle engine. Supposing that, with equal cylinder dimensions, we can obtain more power from the two-cycle engine, it will not be necessary to increase the size and weight of the connecting rods and of the crankshaft, and these portions of the material will therefore be more efficiently utilised. Conversely, for equal powers, the two-cycle engine will be the smaller, the lighter, and in all probability the cheaper of the two, power for power.

As regards loss of heat to the water-jacket, there is very little to choose between the two types, this being in either case about 3,400 to 3,880 B.T.U. per I.H.P. hour, say, 35 to 40% of the total heat in the fuel.*

Charging Arrangements.

With regard to friction and pumping losses, we will take a case where the charge is supplied by a separate pump. A two-cycle engine is somewhat at a disadvantage from the fact that the volumes of air required for combustion must be handled by two separate cylinders. Assuming an equality of the other conditions, this might be expected to involve greater pumping losses in a two-cycle as compared with a four-cycle engine, but the increase of movement of air and gas does not involve a large percentage of extra work, and we may take it that in a small engine the pumping losses amount to a total for a two-cycle engine of 8 to 10% of the I.H.P., and for a four-cycle engine of 6 to 7% of the I.H.P.

Several methods of charging the cylinders of a two-cycle engine have been tried so as to comply with important conditions which must be fulfilled in order that this type of engine should justify its existence. It may be assumed that the two-cycle engine will stand or fall by the efficiency of the scavenging arrangement of its power cylinder, and also that its reliability, capacity, and thermal efficiency will depend upon this. As a general rule also, an excess of air is indispensable in order to drive out the burnt gases effectually, as during this process turbulence is bound to be set up, and there will be to a certain extent an intermingling of the air and the burnt gas. Some of the air must therefore be blown out through the exhaust ports in every case where complete scavenging occurs.

It will thus be seen that in any arrangement of crank case displacement, *i.e.*, where the piston volume swept is the same

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* Taking the calorific value of the fuel at 19,500 B.Th.U. per lb. and consumption = 0·5 lb per H.P. per hour.
= 9,750 B.Th.U. per H.P. per hour.

the loss of heat to the jacket $= \frac{3{,}400 \times 100}{9{,}750} = 35\%$.

on the crank-chamber side of the piston as on the working side, and the chamber itself is utilised as a compression volume for the charge, the maximum that can be hoped for in the way of new charge is a volume equal to piston displacement. Even this will scarcely be reached in practice, on account of the losses occasioned by the transference of heat from the cylinder walls and other masses of metal to the new charge.

There is another point to be borne in mind where crank-case pumping is adopted, namely, that the positiveness of the scavenge ceases when the piston reaches its outer dead centre, unless a receiver of sufficient capacity is interposed and a non-return valve fitted to prevent the air returning to the crank chamber on the upward stroke of the piston. It will be pointed out later on how such an arrangement also suffers by reason of the falling off in pressure of the air supply at a time just before the inlet closes, when a slightly higher pressure would be of considerable benefit.

A further feature in the crank-case system is that, when the front of the piston acts as a compressor, the heat transferred to the charge is considerable, on account of the unsuitable shape of the chamber in which the compression takes place and the leakage that is likely to occur through the bearings. It cannot be denied, however, that such an engine has the feature of simplicity in its favour, and where high efficiency is not a great point it has many things to recommend it.

We may take it now that high efficiency cannot be obtained with crank-chamber compression, and a number of designers have resorted to the use of pistons of two diameters, using the annulus for pumping purposes. In the engine designed by Mr. B. T. Hamilton, multiples of two firing cylinders are used so that when one of the larger pistons is on its ascending stroke, air is blown through above the other piston, which is at the bottom of its firing stroke, the cranks being set at an angle of 180°. An important feature of this engine is a distributing valve situated in the air pipe, for the purpose of admitting hydrocarbon vapour at the proper moment, the valve being rotary and mechanically operated so that any desired regulation can be obtained. In this simple type of engine, whether constructed with a pumping annulus or for use with crank-chamber compression, there is one inherent defect, namely, that the exhaust and inlet ports are in the vicinity of one another, while the exhaust ports are necessarily longer and remain open after the inlets are closed. The effective volume of new charge has a limited maximum, which, assuming that the products of the previous charge are completely dispelled, is only that of the compression space and the working volume to the point of exhaust valve opening and closing. In order to increase the charge volume which it is possible to put into a working cylinder on the two-stroke system,

either the ports must be differently arranged, or the incoming charge must be admitted at the end of the cylinder opposite to the exhaust outlet.

The Lamplough rotary engine, though not at the time of writing a proved mechanical success, has at least a very interesting feature in the arrangement of the admission and exhaust. The cylinders are each fitted with a centrally situated mushroom exhaust valve in their heads, the inlet being through annular ports in the cylinder walls. As the engine is rotary there is the possibility that centrifugal force assists the inertia of the gases in exhausting the cylinders and at the same time the flow path of the incoming charge is a centrifugal one. The Author believes that there is considerable novelty in this arrangement of an engine. (Plate I.)

Passing now to another arrangement of two-cycle engine cylinders we will consider the inverted U type of engine, which is fairly well known. These cylinders are also known as the syphon arrangement and date back at least to 1900 when they were described by Binn, and in 1903 this arrangement reappears in the patent specification of Messrs. Bickerton, Bradley, and Dugald Clerk, of The National Gas Engine Co., Ltd. Here we have also a uni-directional flowpath for the gases, as the two legs of the syphon are combined with a common combustion chamber. The exhaust ports are cast in the walls of one cylinder, whilst the inlet ports are in those of the other cylinder. The advantage claimed for this arrangement is that a longer flowpath is given to the incoming charge and there is less likelihood of the incoming mixture passing unconsumed through the exhaust ports.

Were there such a phenomenon as perfect stratification, it would be possible so to arrange the pressure and volume of the incoming charge that none of it escaped down the exhaust pipe. In actual practice with high-speed engines there is, however, very considerable turbulence, and whatever the arrangement of the cylinders, there is a very great intermingling of the fresh charge with the products of combustion of the previous charge.

The Valveless engine is an example of this principle in actual work, and this engine has proved to be quite satisfactory in many respects. Mr. Reginald Lucas originally used a straight cylinder with two pistons moving in opposite directions, but afterwards reverted to the syphoned arrangement and fitted two crankshafts. In his engine the two pistons descend together and their centre line is transverse to the centre line of the crankshafts. In spite of the increased length of flowpath, this engine suffers from the same objection as exists in many single piston engines, namely, that the exhaust ports, which necessarily open first, close after the inlet port has closed. The ideal arrangement is to close the exhaust port as soon as possible and allow

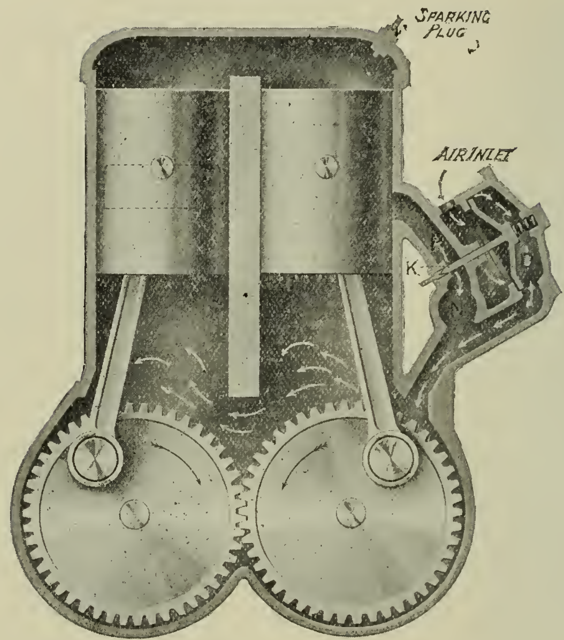


FIG. 2.—THE VALVELESS ENGINE.

the inlet port to remain open with the ever-increasing pressure of the incoming charge.

The arrangement of syphon cylinders in the Lamplough vertical two-cycle engine enables this difficulty of valve setting to be overcome, but at the same time the arrangement of the connecting rods and their design may call for some criticism from strictly engineering points of view. The syphon cylinders are set with their axis transversely to that of the crankshaft, and the two pistons in one unit actuate upon the same crankpin. The accompanying fig. 2, shows the position of the subsidiary crankpin for one of the rods. In this arrangement it is obvious that the two pistons do not synchronise in their movements, and it so happens that with equal port openings the exhaust is opened first and closed first, while, although the relative movement of the pistons is appreciable at the time of firing, the actual volume of the compressed mixture is constant at that moment.

In this type of engine a separate charging pump is necessary for each firing unit, but in carrying out numerous experiments, the author has obtained some advantage by coupling up two compressed mixture reservoirs in a duplex unit in order to increase the effective volume of the waiting charge. In this

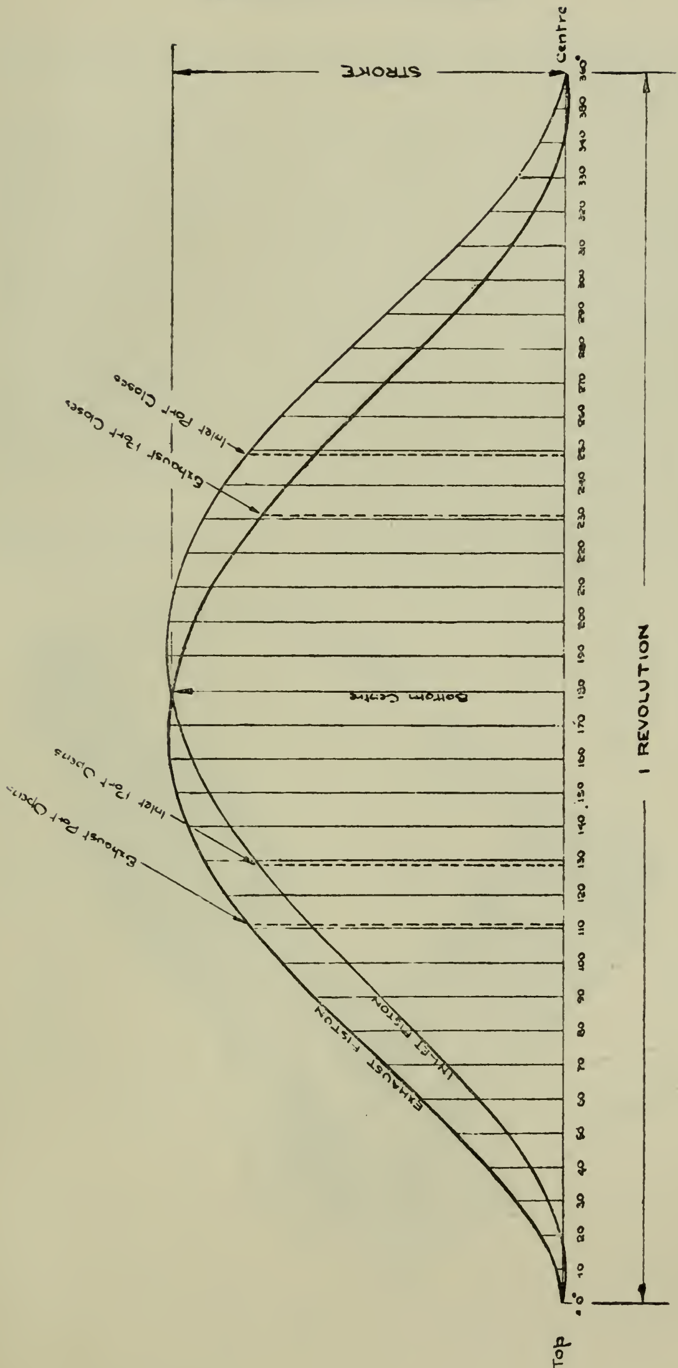


FIG. 3.—PISTON DIAGRAM, LAMPLOUGH ENGINE.

type of engine, air and vapor are dealt with in a single pump, and such scavenging as obtains is carried out by means of the carburated air.

A rotary arrangement as distinct from such a charging device, has many attractions. These rotary charging pumps have been exclusively adopted in conjunction with two-cycle engines for aviation purposes, and in addition to the large pulsating blower which Mr. Lamplough constructed for his aviation engine, there has been a considerable amount of practical demonstration of rotary charging devices by Messrs. Mort, of The New Engine Co. The arrangement of blowers adopted by Mr. G. F. Mort obtains by rotary methods a result similar to that adopted in the Korting engine, separate blowers being used for air alone, and for carburated air. Scavenging is carried out in its proper sequence, a rotary distribution valve being operated by the engine in order that petrol vapor should not be allowed either to pass into a cylinder during a period of flame nor to be blown out of the exhaust passage and wasted.

When perfect scavenging can be carried out without appreciable loss of power, the highest results as regards thermal effi-

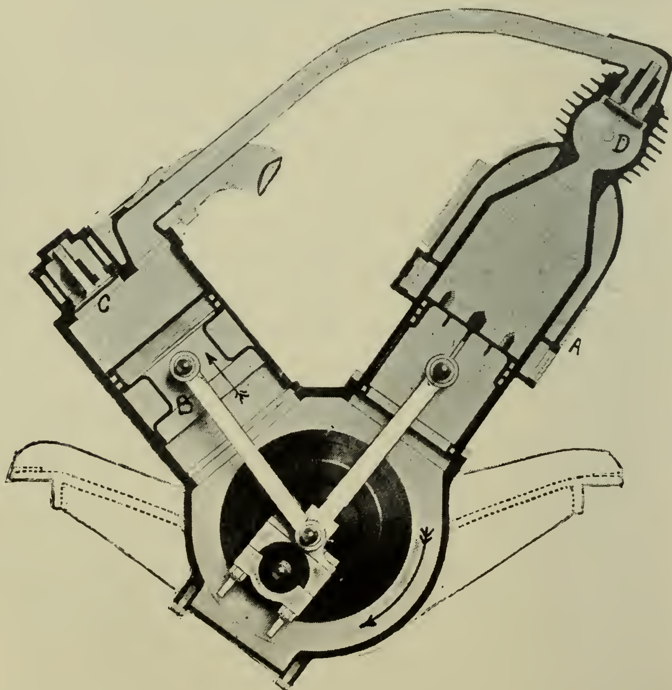


Fig. 4.—The Dolphin Engine.

ciency and mechanical output can be obtained. The New Engine Co. show that with their engine they can develop more than twice the horse-power that can be produced from any ordinary four-cycle engine of similar dimensions.

Theoretically it should be possible to fill the total swept volume plus the volume of the compression space with explosive mixture, unmixed with inert gas, at the beginning of each compression stroke, and if the pressure in the air receivers is exactly at its correct value in any particular case, no great difficulty should be experienced in obtaining a fair approximation to the ideal results. In the Mort Engine the blower pressure is about 5 lb. per square inch and this is found sufficient for the purpose in view. The explosive mixture is only introduced to the cylinder when the inert gases are sufficiently expelled and cooled down to eliminate any possible source of ignition.

TEST ON THE "DOLPHIN" TWO-CYCLE ENGINE.

Revolutions per minute.	B.H.P.	Petrol Consumption.
		Pints per B.H.P. Hour.
1,000	5·0	1·28
1,000	9·5	1·05
1,000	11·6	0·91
1,000	14	0·82
1,000	18	0·78
1,000	19·1	0·75
1,200	21·5	0·71

Revolutions per minute.	B.H.P.	I.H.P.	Mean effective pressure	ηP	Mechanical Efficiency.
			Lb. per sq. in.		Per cent.
400	7·8	9·0	81	69·7	85
600	11·8	14·0	84	70·5	84
800	15·7	19·15	86·2	70·7	82
1,000	19·5	24·7	89·0	70·3	79
1,200	22·5	30	90	67·5	75
1,400	23	34·8	89	58	—

ηP is the mean effective pressure as referred to the B.H.P. produced.

THERMAL EFFICIENCY.

Reference has already been made to the comparative loss of heat to the water jackets in the case of both two-cycle and four-cycle engines, and it has been shown that there is very little difference between the two types. In the opinion of the author the greatest difficulties from a thermodynamic point of view are those of carburation, and high working temperatures.

With regard to the former a quotation from Dr. Watson places in a nutshell the chief difficulty encountered. In his paper on the Day engine, read before the Institution of Automobile Engineers, December, 1910, he states that "unless the richness of mixture is adjusted within comparatively narrow limits, particularly at the high speeds, the engine refuses to work on the two-cycle and only fires on every other stroke. The result of this peculiarity is that, unless the carburetter provides a mixture of uniform richness at different speeds and for different throttle openings, satisfactory working cannot be obtained."

Variations of loading are largely accountable for the difficulty in maintaining uniformity of the mixture when a tortuous path is presented to it. This is still further aggravated when the mixture has been pumped, and precipitation of considerable quantities of liquid takes place in the pump itself, in the receiver, and in the pipes.

During very numerous experiments which have been conducted by the author on two-cycle engines the precipitation has been most manifest, in several instances an engine having continued to run for periods of time almost up to one minute after the petrol supply has been cut off. This of course is an extreme case but it shows that at the admission end of the engine very great difficulties occur in the elimination of thermal

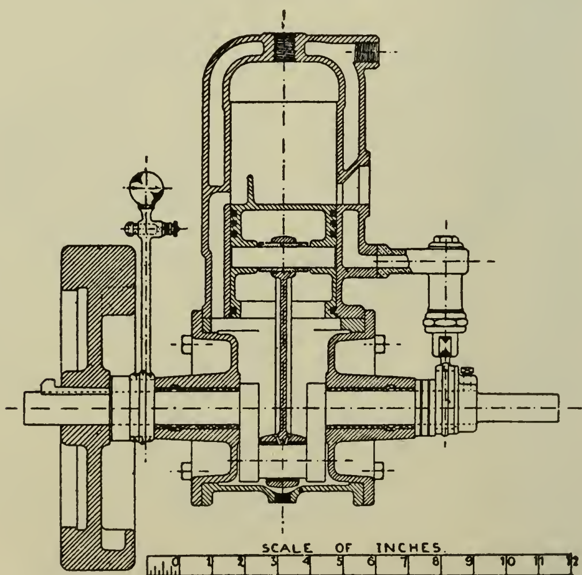


Fig. 5.—The Day Engine.

losses. A study of thermal loss by means of exhaust gas analyses brings to light many points which might easily be overlooked otherwise.

In the four-cycle engine tested by Dr. Watson the exhaust closing and the inlet opening did not overlap and it was therefore impossible for any of the incoming charge carrying oxygen with it to escape unburnt through the exhaust valve. The following example taken from Dr. Watson's paper makes clear his method of calculating the percentage of unburnt charge which escaped from the Day two-cycle engine. The engine itself had a single cylinder with a bore and stroke of $3\frac{1}{4}$in. each. and was rated at 2.5 h.p. at 900 r.p.m. At a speed of 1,218 r.p.m. the exhaust gas analysis gave the following results by volume :—

CO_2	7·4	per cent.
O_2	4·2	,,
CO	5·6	,,
H	2·0	Calculated from % of CO.
CH_4	0·7	
N_2	80·1	By difference.
	100·0	

Taking the fact that air consists of one volume of nitrogen plus 0·266 volumes of oxygen, and that in the above analysis 80·1 volume of nitrogen must have been originally mixed with $(80 \cdot 1 \times 0 \cdot 266 =)$ 21·31 volumes of oxygen, we have in the resulting gas this 21·3 volumes of oxygen, less the 4·2 volumes of O_2 which appears in the exhaust, leaving 17·1 volumes of oxygen taking part in the combustion. The relation of the escaping 4·2 volumes of O to the 17·1 plus the 4·2 (*i.e.*, the total volumes of O introduced) will give the proportion of the escaping air, which we may take as equal to the proportion of the escaping charge.

In this particular test No. 20 of Dr. Watson's the percentage of charge unburnt is therefore 19·7.

Dr. Watson stated in his paper already referred to that, " in the experiments on the four-cycle engine whenever there was carbon monoxide in the exhaust there was no free oxygen." In that particular case all the oxygen present in the explosive mixture combined with the hydrocarbons and as far as the air was concerned the combustion was complete. He goes on further to say that " As a test of the accuracy of the deductions which can be made by this method we may calculate what would be the composition of the exhaust gases supposing we were able to eliminate the proportion of the gases which escape combustion."

DR. WATSON'S TESTS ON "DAY" ENGINE, WITH THE AUTHOR'S ADDITIONAL FIGURES.

TABLE I.—(A. Tests.)

Test Number.	Speed R.P.M.	I.H.P.	B.H.P.	Petrol Pints per B.H.P. hour.	Lb. of Petrol per I.H.P. hour.	Thermal Efficiency, Gross.	Thermal Efficiency, Net.	M.E.P. Lb. per sq. in.	Ratio of Air to Petrol by Weight.	Amount of Charge which escapes, per cent.	ηP
1	636	2·71	2·1	1·64	·917	·149	·230	62·6	11·24	35	48·5
3	638	2·73	2·1	1·50	·830	·165	·252	62·9	12·45	34	48·3
8	903	3·60	2·8	1·65	·923	·148	·212	58·5	10·35	30	45·5
15	907	3·30	2·5	1·28	·702	·195	·276	53·4	14·86	—	40·5
17	1,209	4·12	3·1	1·83	·992	·138	·169	50·1	9·75	18	37·6
18	1,206	4·23	3·3	1·71	·960	·143	·177	51·6	9·91	19	40·0
20	1,218	4·29	3·3	1·52	·847	·161	·201	51·8	10·96	20	40·0
23	1,218	3·79	2·8	1·20	·637	·215	·264	45·7	16·89	—	33·7
24	1,504	4·85	3·6	1·57	·838	·163	·179	47·2	10·06	9	35·0
25	1,514	4·71	3·4	1·59	·825	·166	·177	45·7	10·43	7	33
29	1,500	4·80	3·5	1·35	·703	·195	·208	47·0	12·12	6	34·2
33	1,508	4·91	3·6	1·13	·598	·229	·247	47·9	13·98	—	35
35	1,501	4·52	3·3	1·16	·610	·224	—	44·3	14·85	—	32·4
Throttle Valve partly closed.											
36	639	2·25	—	—	·828	·165	·216	51·7	12·12	25	—
38	896	2·89	—	—	·775	·177	·199	47·4	11·36	11	—
39	1,208	3·55	—	—	·693	·197	·213	43·1	11·73	7	—
40	1,510	3·65	—	—	·669	·204	·209	35·5	12·27	2	—

Returning to the example considered above, 4·2 volumes of oxygen must have been accompanied by 4·2/0·266, *i.e.*, 15·8 volumes of nitrogen, and hence the composition of the exhaust if no unburnt charge were included would be

CO_2 =	7·4 volumes or	9·3 per cent.	
CO =	5·6 ,,	7·0 ,,	
H_2 =	2·0 ,,	2·5 ,,	
CH_4 =	0·7 ,,	0·9 ,,	
N_2 =	64·3 ,,	80·3 ,,	
	80·0	100·0	

Now in the above experiment the air/petrol ratio was 10·96, and from the test on the four-cycle engine the composition of the exhaust gases with this ratio was—

CO_2 =	9·5 per cent.
CO =	7·5 ,,
H_2 =	2·7 ,,
CH_4 =	0·9 ,,
N_2 =	79·4 ,,
	100·0

It will be seen that this method of reckoning is based on the assumption that the combustion of the charge is complete when the exhaust valve opens, and in the absence of definite data to the contrary the author cannot substantiate by figures his theory that this is not the case. The presence of incompletely consumed charge at the moment the exhaust valve opens would materially alter the value of the proportion of unconsumed charge wasted. In numerous tests of four-cycle engines which have been made under the auspices of The Royal Automobile Club various proportions of carbon monoxide above and below two per cent. have been shown.

With further reference to the incompleteness of combustion in a four-cycle engine, reference may be made to Mr. Dugald Clerk's tests with a 18 h.p. Siddeley-Wolsley car, taking examples to illustrate the possibility of there being CO and free O in the exhaust during the same test.

Mr. Dugald Clerk's Tests.

	Engine unloaded at 600 r.p.m.		Car at 18 m.p.h., throttle slightly open.		Full load, 1,000 r.p.m., throttle full open, uphill.	
CO	3·6	1·8	6·9	2·4	3·6	2·2
H	1·2	0·6	2·4	0·8	1·2	0·8
CH_4	0·3	0·3	0·9	0·3	0·4	0·3
CO_2	10·8	5·6	9·9	11·0	11·7	11·8
O	2·2	10·6	0·3	2·2	0·1	0·6
N	81·9	81·2	79·6	83·3	83·0	84·3
		b				

Figures show percentage by volume.

b Samples taken soon after starting the engine.

These results show how very erratic may be the combustion of hydrocarbon vapour and air under ordinary conditions, as distinct from the special tests made in laboratories, where the best results are aimed at.

A two-cycle engine is exhausted as a rule at an earlier period in the working stroke than a four-cycle engine, and it is reasonable therefore to assume that the combustion is not so complete in the two-cycle as in the four-cycle engine.

In the results which the author gives of some of his tests, the proportion of the escaping charge is calculated on the basis of a condition of combustion showing 2% of free oxygen in the exhaust due to the incompleteness of the combustion, the remainder being loss of charge. For comparison, figures making no allowance for the incompleteness of the combustion are given in brackets. Calculating for the excess of air beyond that theoretically required we may proceed in the same manner and

still taking the same test No. 20 the amount of CO is 5·6, and to burn it to CO_2, $\left(\frac{5\cdot6}{2}=\right)$ 2·8% O_2 is required.

The total O_2 present in this case in the exhaust is 4·2%, so that (4·2–2·8 =) 1·4% O_2 out of a total of 21·3 = 5·6% excess of air only is present in this case. The tables given in the paper are all calculated in this manner.

Referring now to the author's tests on engine No. 1, this engine had two firing units, each unit consisting of a pair of firing cylinders with a common combustion chamber and one charging pump. The cylinders are what as known as the syphon arrangement, and the pistons are 2½in. diameter by 3½in. stroke. The inlet ports and exhaust ports were half an inch wide, that is, the exhaust opened 85% on the downstroke of piston travel. The displacement volume of a pair of pistons was 34·3 cu. inches. The charging pump for one firing unit had a piston of 3⅜in. diameter by 3½in. stroke and its displacement volume was 31·5 cu. in. per stroke. The swept volumes of the pistons to the point of exhaust closing amounted to 27 cu. in. per pair, slightly less than the displacement volume of the charging pump. Putting these figures into values more easily dealt with for our purpose, they represent at a 1,000 r.p.m. of the engine a blower capacity of 36·5 cu. ft. per minute and a cylinder capacity of 31·2 cu. ft. per minute, for a complete engine of two firing units. It will be seen on reference to the table how the theoretical capacity of the blower is practically reached in some cases and very nearly so in the majority of the tests, but these measurements were only made with some difficulty by means of an anemometer, there being no available appliance of a more suitable nature.

A large number of observations were made with great care, the calculations of the ratio of air to petrol by weight being based on these observations.

Method of Testing.

Two engines were fitted side by side and tested alternately. The temperature of the testing room was 63° Fah. on an average, and that of the inlet water 62° Fah. at the time of starting each day. The brake used was a Walker dynamometer, and two sizes of plates were employed throughout these experiments in order to avoid any possible errors in the dynamometer, the dynamometer itself being checked by being driven on a free shaft by an electric motor. The consumption of energy was measured by a Kelvin wattmeter.

The average length of the tests was half to three-quarters of an hour, and in the first three, the water temperatures were as follows :—

	Inlet.	Outlet.
Start	62° F.	84° F.
Half-time ..	75° F.	96° F.
End	97° F.	117° F.

Then we have in test 4 a mean inlet temperature of 78° Fah. and an outlet of 98° Fah., and in test 5 an inlet temperature at the start of 66° Fah. and outlet 87° Fah. At the end of the test this rose to 84° inlet temperature and 98° Fah. outlet temperature.

As these temperatures were much lower than would be obtained in actual practice on a motor-car, some of the tests were run with higher jacket temperatures as for instance 102° inlet and 116° outlet at the beginning of the test, rising to 149° inlet and 162° outlet at the end of the test. In this latter case the engine was running very steadily at 1,500 r.p.m.

Lamplough Two-cycle Engine.—Summary of Preliminary Tests.
(Author's First Set of Consumption Tests.)

Test.	Duration of Test.	Petrol Consumption, gals. per hr.	Revs. per Min.	B.H.P.	Petrol per b.h.p. hour, gals.	Petrol per B.H.P. hr. pints
1	2 mins.	0·93 & 0·92	930	8	0·12	1·0
2	12 ,,	0·95	710	4	0·24	1·9
4	2 ,,	1·5	1,453	11	0·14	1·1
5	26 ,,	1·64	1,500	12	0·14	1·1
6	5½ ,,	1·86	1,510	12	0·15	1·2
7	9 ,,	2·13	1,569	12·17	0·16	1·3
8	30 ,,	5·1 kilo	1,428	10	0·17	1.3
9	18 ,,	1·33 gals.	1,467	10·5	0·13	1·0
10	10 ,,	0·96 ,,	1,200	6	0·16	1·3
11	25 ,,	4·63 kilo. 6·4 litre	1,066	13·3	348 grams	0·7
12	18 ,,	—	1,050	12·2	380 ,,	0·9
13	27 ,,	1·48 gals.	1,500	11·4	0·13 gals.	1·0
14	20 ,,	1·92	1,500	11·4	0·17	1·4

1. Air 32 cubic feet per minute. Claudel carburettor, 18mm. × 0·95 jet.
2. Welsh carburettor. Jets 4 and 4.
4. Air 52 cubic feet per minute.
5. Welsh carburettor. Jets 4 and 1.
6. Welsh carburettor. Jets 4 and 3.
7. Welsh carburettor. Jets 4 and 4. Compression 86 lb. per sq. in.
8. 0.720 Shell. Claudel carburettor, 18mm. × 0·95 jet;
9. 0.760 Shell. Claudel carburettor, 18mm. × 0·95 jet.
10 Half throttle. Air 25·6 cubic feet per minute.
11. 0.720 Shell spirit. Air 48 cubic feet per minute.
12. Solid petrol, 0·760 sp.gr. in the liquid.
13. Lamplough carburettor. Jet 10 grooves each 10/1000in. deep.
14. Claudel carburettor. 26mm. × 1·20 jet.

AUTHOR'S TESTS OF A LAMPLOUGH TWO-CYCLE ENGINE.—No. 1. January 25th to 31st, 1911.

Test.	Revs. per min.	Petrol Consumption. Gals. per hour.	Petrol Consumption. Pints per B.H.P. hour.	B.H.P.	Air, cubic feet per minute.	Ratio, Air to petrol by weight.	Per cent. blower full.	Carburettor.	Brake, Size of Plates, and Point of Location.	Exhaust Gas Analysis per cent. by volume. CO_2.	O_2.	CO.	N.,&c.	Per cent. excess of air.	Per cent. loss of charge.	ηP=mean pressure referred to B.H.P.
C. 10	400	—	—	0	—	—	—	Lamplough	$8\frac{1}{2}$in. × 11in. in 4th hole	6·4	6·5	4·3	82·8	19·8	20·5 (30)	—
B. 8	800	0·88	1·67	4·2	17·6	12·8	61	Claudel Hobson 18mm. × 1·0, half open	$8\frac{1}{2}$in. × 11in. in 7th hole	5·0	6·6	6·9	81·5	14·3	20·8 (30·6)	30·5
C. 11	1,225	1·50	1·16	10·3	40	17	91	Lamplough	$8\frac{1}{2}$in. × 11in. in 4th hole	4·5	5·1	9·1	81·3	2·5	14·1 (23·2)	48·7
C. 13	1,240	1·33	0·97	11·0	42	20	94	Claudel Hobson 18mm. × 0·95	$8\frac{1}{2}$in. × 11in. in 4th hole	7·1	4 6	5·5	82·8	8·4	11·8 (20·8)	51·2
C.13*b*	1,240	2·0	1·46	11·0	42	13·4	94	Claudel Hobson 18mm. × 1·0	$8\frac{1}{2}$in. × 11in. in 4th hole	—	—	—	—	—	—	—
C. 9	1,225	1·48	1·02	11·5	40	17·3	91	Claudel Hobson 18mm. × 1·0	$8\frac{1}{2}$in. × 11in. in 6th hole	5·5	5·1	7·0	82·4	7·3	14·1 (23·2)	54·2
B. 7	1,820	2·12	1·41	12·0	—	—	—	Claudel Hobson 18mm. × 1·0	6in. × 6in. in 8th hole	3·3	6·1	6·8	83·8	12·3	18·6 (27·6)	38·2
B. 6	1,560	1·58	1·0	12·6	56	22·5	100	Claudel Hobson 18mm. × 1·0	6in. × 6in. in 15th hole	6·4	5·5	5·2	82·9	13·2	15·9 (25·0)	46·7
B. 8*b*	1,480	—	—	13·5	50	—	95	Claudel Hobson 18mm. × 1·0	$8\frac{1}{2}$in. × 11in. in 2nd hole	—	—	—	—	—	—	52·7
C. 12	1,370	1·89	1·0	15·0	49·5	16·7	100	Claudel Hobson 18mm. × 0·95	$8\frac{1}{2}$in. × 11in. in 4th hole	9·0	5·9	1·5	83·0	23·3	17·7 (26·7)	63·2
B. 7*b*	1,970	—	—	15·1	—	—	—	—	6in. × 6in. in 8th hole	—	—	—	—	—	—	44

The average value of ηP for four-cycle engines of similar dimensions is 54 to 58 lb. per square inch.

The figures not in brackets in the penultimate column are calculated on the assumption of a normal presence of 2% of free oxygen in the exhaust of I.C. Engines. The average length of the tests was half to three-quarters of an hour.

Author's Tests of a Lamplough Two-cycle Engine.—No. 2. January 20th, 1911.

Test.	Revs. per min.	Petrol Consumption. Gals. per hour.	Petrol Consumption. Pints per B.H.P. hour.	B.H.P.	Air cubic feet per min.	Ratio, Air to petrol by weight.	Per cent. cylinder full.	Carburettor.	Exhaust Gas Analysis. Per cent. by volume. CO_2	O_2	CO	N.,&c.	Per cent. excess of air.	Per cent. loss of charge.	ηP = mean pressure referred to B.H.P. lb. sq. in.
A 1 ..	1,200	—	—	—	—	—	—	Lamplough	7·3	8·1	1·4	83·2	35·2	27·7 (36·5)	—
A 2 ..	1,000	0·59	0·94	5	—	—	—	Do. ½ throttle	8·2	8·5	0·4	82·9	37·7	29·5 (38·5)	29
A 3 ..	1,635	1·65	1·34	9·85	—	—	—	Do. fullthrottle	6·6	5·3	5·9	82·2	10·9	16·0 (25·0)	34·7
A 4 ..	1,550	1·33	0·85	12·5	49·2	23·6	88	Claudel Hobson 18mm. × 0·95jet.	6·6	6·6	4·0	82·8	21	20·5 (29·5)	46·7
A 5 ..	1,350	1·08	1·01	8·5	32	18·8	66	Claudel Hobson 18mm. × 0·95jet.	6·3	4·0	6·8	82·9	2·7	9·1 (18·2)	36·4

The author allows 2 per cent. free O as due to incomplete combustion.

The figures in brackets are obtained by Dr. Watson's method, assuming that all the oxygen is burnt except such as passes through the exhaust port before compression.

Remarks on the Tests on Engines Nos. 1 and 2.

A little difficulty was experienced in the test shop due to pre-ignitions when the water temperature was high, and the engine sometimes slowed down and stopped through this cause. On the track, these difficulties were met with at first, but were afterwards got over, although the engine was running very hot. Referring now to engine No. 2 which was the first one tested, in tests 1, 2 and 3 the engine was as originally designed, with the gas receiver pockets covered with flat plates. In tests 4 and 5, these covers were replaced by a pair of covers giving a slightly increased capacity to the receivers, as it was noticed that the loss of charge was considerably high, particularly at half throttle. The improvement is shown when the proportion of O_2 in test No. 5 is reduced to 4% as compared with 5·3% in test No. 3. No. 1 engine was then taken and larger covers fitted to its air receivers and tests No. 6, 7, 8 and 9 were then made, but the proportion of O_2 in the exhaust was still high. It will be seen also that in these four tests a larger jet, namely 1·0 mm. diameter, was fitted to the carburettor, in place of the 0·95 mm. jet previously in use. No. 7 shows up particularly badly as far as the CO_2 is concerned, and this may perhaps be accounted for by the high rate of revolutions of the engine, in this case 1,820 per minute. We also note that the escaping oxygen has a high value, and the probability is that the combustion was not nearly complete at the time of exhaust opening. In tests No. 10 to 13 the pocketed covers were replaced by flat covers coupled together by a 1 inch diam. pipe and here perhaps the best results were obtained. No. 10 was a light test showing 4·3% of CO in the exhaust with a Lamplough carburettor in ordinary adjustment and not tuned up. Test No. 11 is an attempt to obtain full power with this arrangement and it will be seen that the CO is enormously high owing to a deficiency of air. The CO_2 is low on account of the incomplete combustion. In No. 12 test a great improvement has been made. The Claudel Hobson carburettor was fitted and the B.H.P. increased from 10·3 to 15·0, with an increase of engine revs. of only 145. We now have 9% of CO_2 and only 1·5% of CO, thus giving the best test obtained up to date.

Mechanical Results of the Tests.

As the tests which the author has carried out were purely for mechanical ends, no question of the indicated horse-power of the engine came in. In this way the author's tests differ from those more scientific tests of Dr. Watson and some of the results obtained by the latter have been modified and brought into line with the author's tests for comparison. The internal friction and pump losses of the two-cycle engine under discussion were measured as accurately as possible by driving the engine

with an electric motor, and the following table shows some of the results obtained.

Throttle Opening.	Motor driven at 900 r.p.m.	
	Air.	H.P. required
	cubic feet.	
$\frac{1}{4}$	10·8	1·9
$\frac{1}{2}$	26·4	2·1
$\frac{3}{4}$	35·2	2·3
1	41·6	2·5

The most interesting and useful information that engineers now require is the value of ηP*. In the author's tests these values are given in the last column and it is interesting to compare them with the average values of ηP for four-cycle engines of similar dimensions.

Taking the cylinder dimensions as 2·5in. diameter and 3·5in. stroke the combined area of four pistons is 19·5 square inches. Referring to test No. C. 12 we have a B.H.P. of 15·0 at 1,370 r.p.m.

$$\text{therefore } \eta P = \frac{33{,}000 \times \text{B.H.P.}}{A \times L \times N}$$

$$= \frac{33{,}000 \times 15 \times 12}{19 \cdot 5 \times 3 \cdot 5 \times 1{,}370}$$

$$= 63 \cdot 2 \text{lb. per sq. in.}$$

In the above case N equals the number of revolutions per minute, as the pistons receive an impulse every revolution.

If we now compare this value of ηP of 63·2lb. per sq. in. with the figure given by Mr. G. A. Burls, in tests No. 52 and 53, in his paper read before the Institute of Automobile Engineers, we find that for a cylinder diameter of 2·4ins. in the first case the value becomes 61·2lbs. per sq. in. with a 10 h.p. engine, and in the second case, test 53, the cylinder diameter is 2·56ins., the horse power is 11·5 and the value of ηP 63·8 lbs. per sq. in.; these are for four-cycle engines. Making a comparison therefore, we find that the two-stroke engine shows up very favourably against the four-stroke engines referred to in Mr. Burls' tests.

As the engine in question is in no way a racing model and no special care was taken to lighten the reciprocating parts, we will make a comparison of the value for this pressure with the results obtained by Mr. Poppe's formula in the calculation of brake horse power, where B.H.P. $=0 \cdot 81(d-0 \cdot 79)^2$ † and taking Mr. Burls' equation where σ denotes the piston speed in ft. per min. B.H.P. per cylinder $=1/68{,}000\ d^2\ \eta P\sigma$.

* ηP is the mean effective pressure as referred to the B.H.P. produced.
† According to this formula for 4 cylinders 2½in. dia. the B.H.P. = 9·5.

Mr. Poppe's formula therefore gives $\eta P = 136 \times \left(\frac{(1-0 \cdot 79)}{d}\right)^2$.

So that for a cylinder diameter of $2 \cdot 5$ ins. $\eta P = 63 \cdot 5$ lbs. per sq. in.

Conclusion.

From the foregoing investigations it will be evident that in certain quarters quite a lively interest in the development of the two-cycle engine exists, though it will be a long time before the present high state of efficiency of the four-cycle engine is either reached or exceeded. There is no doubt, however, that rapid advances are being made in two-cycle engine development, but the difficulties in the path of a designer are very much greater than any which occur in the better known type of Otto cycle engine. At least one English manufacturer claims to have produced twice as much power, for an equal cylinder dimension, as is ordinarily produced by a four-cycle engine, but it must not be forgotten that with special methods of construction and tuning up which four-cycle engine men are acquainted with, it is possible to produce from quite small four-cycle engines abnormally high powers not dreamt of a few years ago. Very much still remains to be done before the two-cycle engine will be able to claim any large measure of support, and it is hoped that this paper will stimulate others to carry on that most important and interesting development, namely the perfection of the two-stroke internal combustion engine.

APPENDIX.

The Fox Two-cycle Motor.

This engine embodies the very latest American ideas in its construction, so it may be taken as representative of its class in that country. The Fox two-cycle engine is divided into three classes, viz., twoport, threeport, and fourport motors. It is the author's intention here to explain the working of the threeport engine, which was designed to secure higher speeds than were available in the twoport engine, and also to eliminate the checkvalve used therein, which will not act quickly enough for high-speed work.

The *modus operandi* of this engine is as follows :—The piston on its upward stroke, uncovers a part in the cylinder walls, allowing the fresh charge of carburated air to be drawn from the carburettor into the crankcase.

The previous charge of fuel having passed from the crankcase through the intake port into the cylinder is now highly compressed

by the ascending piston. At a point near the end of the down-stroke, the piston uncovers the exhaust port on the left hand side of the cylinder (see fig. 6) and the burnt gas passes out of the cylinder into the exhaust manifold and to the open air.

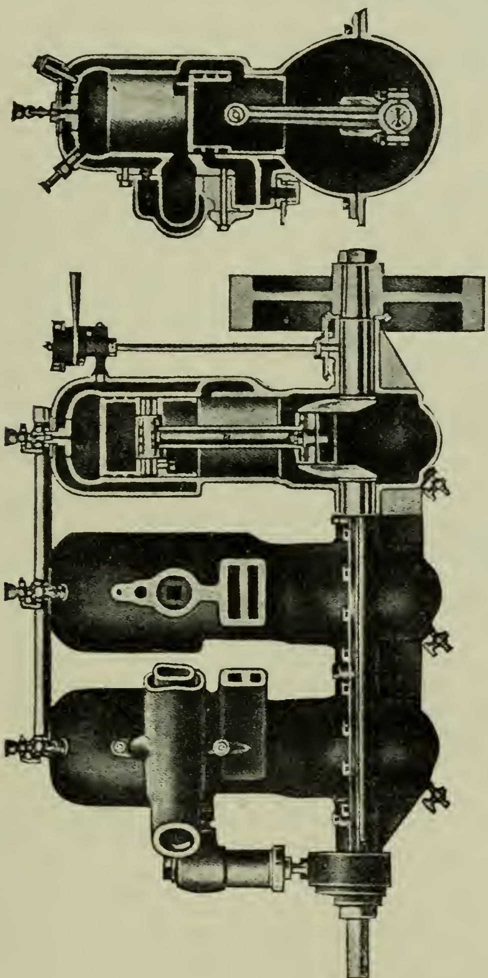


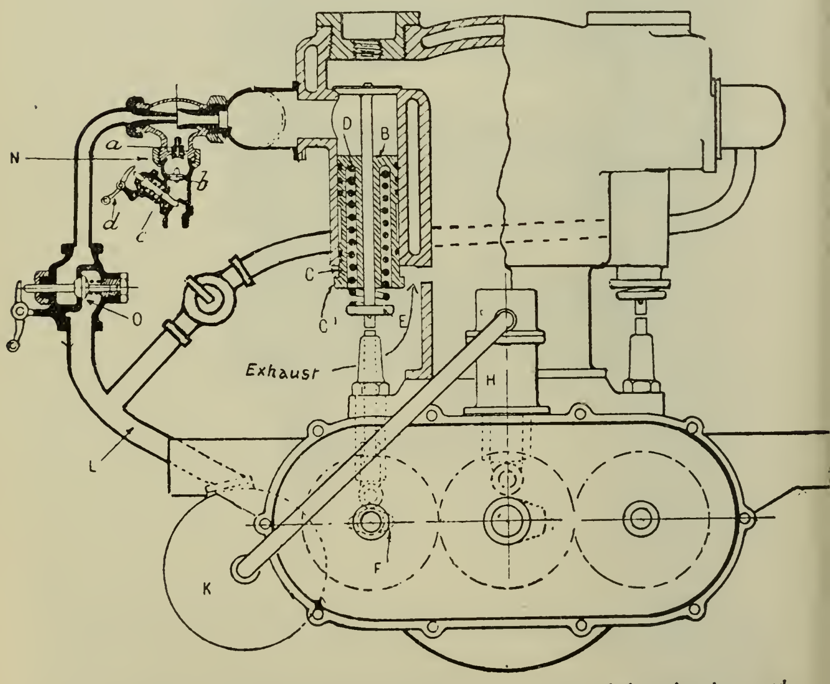
Fig 6.—Fox Engine.

Immediately after opening the exhaust port, the piston, still descending, opens the intake port in the cylinder walls communicating with a transfer passage to a lower port, which registers with a port cut in the side of the piston itself. The partially compressed mixture passes from the crankcase through the side of the piston and by means of the transfer port to the working cylinder.

Now while the threeport motor marks a distinct advance over the twoport motor in the matter of feed, it was soon observed that the actual power of the motor did not increase in proportion to the increase of speed, owing to the fact that at high speed the third port is open so short a time that it is impossible for a sufficient volume of gas to enter the engine. This observation led to the use of combination two and three port motors, increasing the amount of the gas admitted.

The Gore Two-Stroke Aero Engine.

This engine is provided with a compressor H, gear driven at half engine speed from the crankshaft, and this forces air under pressure into a receiver K. The receiver is connected with the inlet side of the gas generating device N by a pipe L, in which is a stop valve O. The gas generating device is connected with the gas inlet valve pockets of each cylinder by the usual induction pipe. The scavenger valve pockets are also connected by an induction pipe to the receiver.



A part section of the Gore engine showing the air pump, balanced valves, and carburetter. This drawing is not to scale.

Fig. 7.

The mechanically operated gas and scavenging valves are of the usual construction, and bear on seats formed in the valve chambers. They are retained in the seating by springs D acting on the stems of the valves through the usual cup and cotter E. The stems of the valves, instead of sliding in the guides B, work in sleeves or pistons C, the latter being also arranged to slide in the guides. The pistons C are each provided with piston-rings, also with metallic packing rings for the valve spindles, and with a flange C′, which operates as a stop by engaging the underface of the guides B, and limits the upward movement of the pistons when at rest.

Owing to the method of mounting both inlet valves, the pressure of the compressed gas and air in the inlet valve pockets of the cylinder cannot open the valves, as the pressure tending to lift the valves reacts upon the pistons, so that the pressure on the valves is opposed by that acting through the guide sleeves to keep the valves on their seats. In other words, the inlet valves are balanced, and therefore, notwithstanding the pressure of the compressed gas and air in the valve pockets, the valves can only be opened by the cam F in the usual manner.

The construction of the gas generating device is clearly shown. The body N contains two cones and a fuel jet *a*, below which is fitted an automatic non-return valve *b* and an adjustable needle feed *c* actuated by a lever *d*. The fuel pipe is attached to this body. The action of the gas generating device is as follows :—

On opening the main compressed air valve O, the compressed air rushes into the first cone at a high velocity, creating a vacuum below the fuel jet *a* and lifting the non-return valve *b*. There being a vacuum, the atmospheric pressure forces the fuel through the the jet *a*. The fuel on entering the body N is (1) caught by the inrushing compressed air, and is atomised ; (2) as the compressed air is of a higher temperature, the fuel is also vaporised. This action is instantaneous and simultaneous, and this combination is made under pressure. When the engine is working, the pistons C are floating pistons. There is no hammering because they never seat, and the load on the springs is very light.

Two cams are provided for each gas and scavenging inlet valve. These cams form an inclined plane and are slightly spiral (fore and aft), and both cam shafts are capable of sliding, being operated by suitable small levers fixed in any convenient position ; both camshafts are driven at engine speed.

The engine is controlled (1) by valve gear, *i.e.* sliding inlet (gas) camshaft ; (2) by main compressed air valve which acts as a throttle ; or (3) by using both together.

The sliding inlet (gas) camshaft gives a variable cut-off and with it the means of raising or lowering the mean effective

pressure acting on the power stroke, and thereby governing the output of the engine.

The gas supply is independent of the cycle of operations, therefore the power output is not limited by the rate of piston speed. This permits of an increased supply of gas under pressure to an engine labouring under an increasing load and at the same time making the motor self starting. As the rate of the revolution decreases the bulk of the gas can be increased, so as to maintain a steady torque at low piston speeds. The scavenging valves are always working at their maximum lift. The reversing is effected by sliding both camshafts forward.

The gas and scavenging air can be admitted at any point of the stroke, and as only pure air is compressed, no pre-ignition can take place, even at the highest working compression ; the charge can also be fired automatically, *i.e.*, by compression, should the ignition gear break down. Both mechanically operated valves pass only cool gases, and their opening is assisted by the pressure on their undersides. This pressure also acts as a cushion upon the closing of the valves. The compressor is provided with a simple automatic unloading device, which regulates the load on the compressor to the exact amount of air used.

Three working pistons 3·5in. diameter by 5in. stroke, having a volume swept by the pistons of 144·3 cu. in., would develop at 1,000 r.p.m. 32·6 h.p., on a consumption of 0·4 pints per h.p. hour, the fuel being paraffin at 6½d. per gallon.

The Godfrey-Evans Two-cycle Engine.

A single unit of this engine consists of a pair of twin cylinders open at their lower end and communicating with one another at the bottom and centre, each cylinder containing two pistons working in opposite directions.

The cylinders are arranged transversely to the crankshaft and the two lower pistons actuate a common crankpin. The upper pair of pistons transmit their thrust by means of tail-rods passing through glands in the cylinder head on to a common crosshead and thence to the crankshaft by means of two return connecting rods.

The crosshead takes the form of a large diameter piston which is used as an air pump for scavenging. The cycle of operations is as follows :—

Considering that the pistons are at their outermost position, the top side of the upper pair of pistons, which forms virtually a syphoned cylinder, is used as a pump for drawing in a richly carburated air. The pistons on their receding stroke draw in, in addition, a certain amount of slightly compressed air from the scavenging pump. On the return stroke this mixture is compressed until one of the pistons over runs a transfer port from its upper to its lower face. At this time the carburated

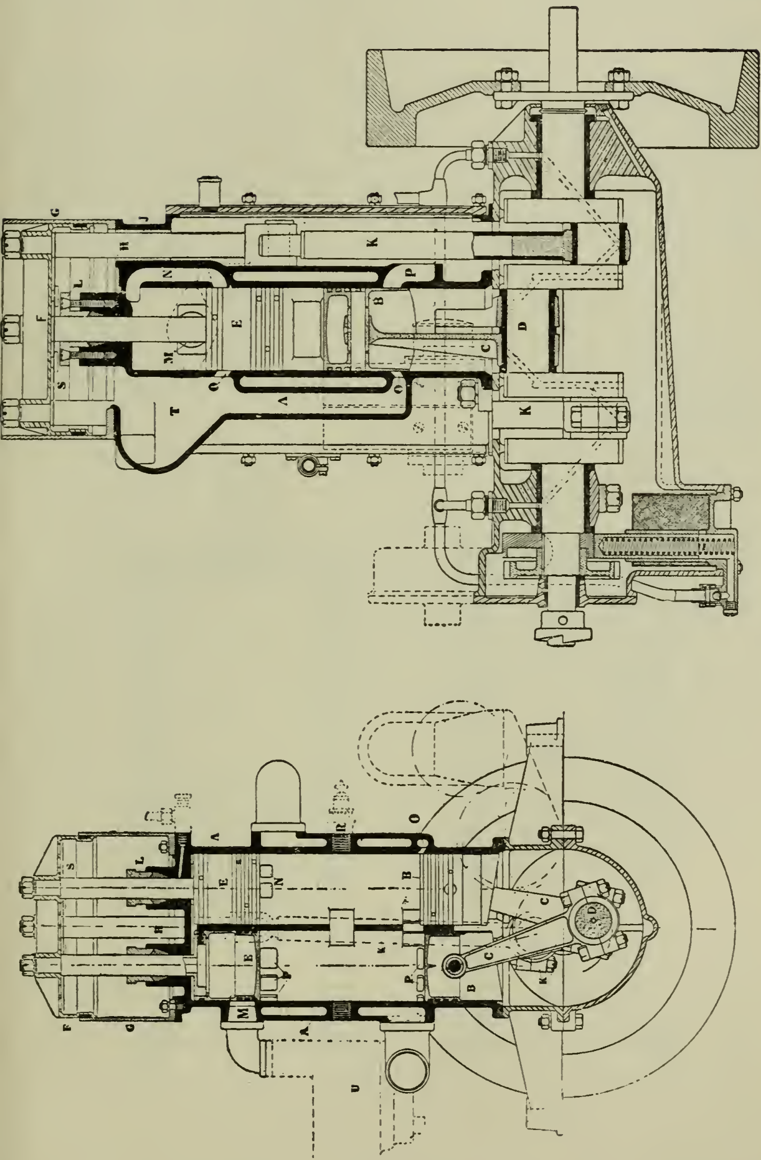


FIG. 8.—THE GODFREY-EVANS ENGINE.

air is passed into the working volume between all the four pistons. Considering now the working part of the cylinder and assuming that these cylinders represent the letter H, the exhaust is expelled from the upper and lower extremity of one limb

Shortly after, the scavenging ports at the upper and lower extremity of the other limb are uncovered and air under pressure enters the twin cylinder and is transferred from one limb to the other through the centre connecting port. The pistons have now passed their dead centre and the rich charge enters the system through the single transfer ports before mentioned. The usual compression, ignition, and expansion then takes place.

THE HAZELTON TWO-STROKE ENGINE.

This engine is primarily designed to overcome the many disadvantages arising from the use of pumps, or crankchamber compression, without materially increasing the number of working parts.

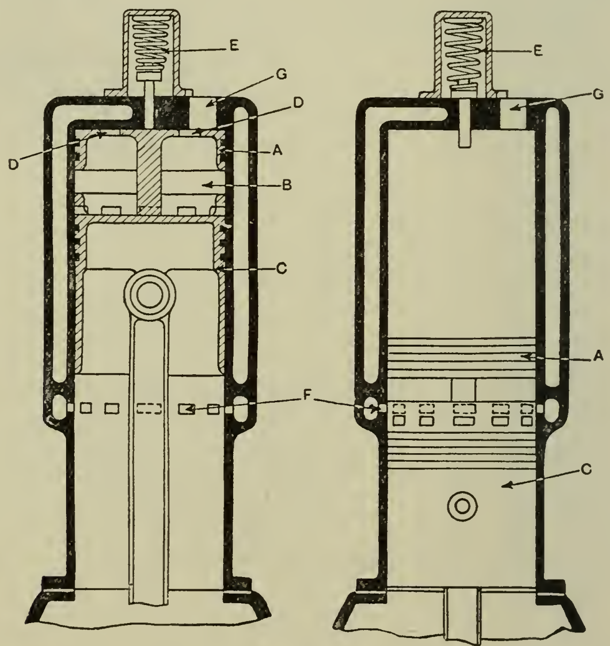


FIG. 9.—THE HAZELTON ENGINE.

The general construction differs very little from that of the ordinary four-cycle engine, the chief alteration being the addition of a second piston, which is practically a partition, free to slide

in the cylinder and fitted with valves which may be of poppet, ball or any other suitable type.

Method of Operation.

On the down stroke the explosion takes place between the pistons, pressing the top piston against the cylinder head and compressing a spring that is fitted to the latter. The main piston being driven downwards in the usual way, uncovers the exhaust ports, thus releasing the pressure on the top piston, which descends very quickly by the pressure of the spring, sweeping the exhaust gases out of the cylinders and at the same time drawing in the mixture for the next stroke on its top side. On the upward stroke the gases are compressed, passing at the same time through the valves in the loose piston to the space between the pistons.

The method of operation can be more easily understood by reference to Fig. 9, which is more or less diagrammatic, in which the first figure shows the positions of the pistons at the commencement of the down stroke. In this position the gases are in compression in the space B, and are ignited in the usual way, driving the main piston C downwards, the piston A retaining its position and the spring E being kept in compression by the explosion. When near the end of the downward stroke the piston C uncovers the exhaust ports F; the pressure on the piston A being thus released it descends by pressure of the spring E, sweeping the exhaust gases through the port F, and at the same time drawing in the mixture for the next stroke through the inlet valve at G. On the up stroke compression takes place in the top part of the cylinders, causing the valves at DD to open, allowing the gases, when fully compressed, to occupy the space B between the pistons. It should be noted that the exhaust ports F are shown to close again before the end of the downward stroke thus causing a cushioning effect on the downcoming piston A.

The Micklewood Two-cycle Engine.

Among the many ingenious designs for two-cycle engine charging arrangements is that of Mr. E. H. Micklewood, in which the differential trunk piston is employed, but in this case the annulus is doubly acted upon. By means of an internal stationary trunk fitting inside the piston, both the upper and lower faces of the annulus are used for pumping purposes. The lower draws in pure air on the upstroke and expels it into the working cylinder through a non-return valve for scavenging purposes on the downstroke. The upper part of the annular piston acts similarly and confines itself to the induction and compression of the charge, which is thus forced past a non-return valve into the combustion chamber

at the same time as compression is taking place. The exhaust is placed about three-quarter way down the working cylinder and is governed by a piston valve having a very quick action, the opening being set to take place after the main piston has passed the port, and is within a quarter of an inch of the end of the stroke, but it is closed on the upstroke by the main piston. The engine therefore provides a positively pumped air scavenge and a separately forced and compressed explosive charge, thus obtaining the desirable features of the Korting engine in a very compact form. The diagram (Plate II.) shows the arrangement of this engine and it will be noticed that the flowpath of the exhaust gas and the incoming charge is uni-directional. The engine is termed "super-atmospheric" and it will be noticed that the piston on its downward stroke uncovers the exhaust port in the usual manner at the same time that the scavenging end of the air pump is compressing air into the vertical pipe communicating with the valve in the cylinder head.

When the pressure in the working volume is reduced, during the exhausting period, to below that in the air scavenge pipe, the valve opens, and a positive scavenge of air follows the exhaust gases through the cylinder. The automatic air inlet valve allows the fresh charge of air to be drawn into the annulus during the upward stroke of the piston. After scavenging has taken place and the piston has returned over its outer dead centre, the annulus is acted upon in compression. This annulus has previously been filled with carburated air through the inlet valve, which is mechanically operated. On the upward stroke of the piston the automatic valve is lifted and the new charge passed through the cored passage to the working cylinder. This transference of charge continues until the pressure in the working volume causes the valve to close, as for instance when the ignition occurs or when the top dead centre is reached.

Discussion.

The **Chairman** proposed a vote of thanks to the author for his very excellent paper, in which the results of the author's own experiments had been brought forward. It should be borne in mind in the discussion that the modern developments were, in a sense, a reversion. The early engines were two-stroke, but, on the expiration of the Otto patent, everyone went over to four-cycle engines, and, therefore, as had been pointed out, the position of the two-cycle engine was not what it otherwise might be.

The vote of thanks was unanimously agreed to.

The following communication from **Dr. W. Watson, F.R.S.** was read by the Secretary.

"I have read Mr. Brewer's paper with great interest, and the portions of the paper which interest me most are naturally those which deal with the method of deducing the amount of the loss of charge as adopted by Mr. Fenning and myself in our test of the Day two-cycle engine. Mr. Brewer suggests that at the time when the exhaust port opens (about 70 deg. before out-centre) combustion is still going on. He further tacitly assumes, that directly the gases escape from the cylinder the combustion which was in progress is immediately stopped, for of course if combustion were to continue in the exhaust pipe his method of calculation at once breaks down. Now a very great amount of experimental work has been done with reference to the question of how long combustion continues on the working stroke of an engine, and I think I am right in saying that it has been clearly shown that combustion has proceeded as far as it will ever go very shortly after maximum pressure is reached, that is, with normal timing of the spark, long before the exhaust ports are opened on the Lamplough engine. With very weak mixtures, maximum pressure may be so late that combustion is still going on when the exhaust port opens, but Mr. Brewer has not used any such weak mixtures, for with them there would be no CO in the exhaust. The irregular results obtained in the case of the R.A.C. tests as well as in Mr. Dugald Clark's tests are probably not due, as the author suggests, to "erratic" combustion of hydrocarbon vapour and air, but to two causes (1) Different cylinders in a multi-cylinder engine receiving charges of different strengths, so that while one cylinder is discharging a certain proportion of CO into the exhaust pipe, another cylinder is discharging free oyygen. (2) Errors in collecting the sample of exhaust gases. In all engines which I have tested the pressure in the exhaust manifold sinks during a part of the stroke below atmospheric pressure, hence air is sucked in through all leaks, such as alongside the exhaust valve stems and the like. Further unless a non-return valve is fitted to the outlet of the sampling vessel an uncontaminated sample of the exhaust gases cannot be obtained. In every case, both in the test room and on the road, when I have found both CO and O in the exhaust, careful examination has shown the presence of leaks, and when these are prevented there is never both CO and O at the same time.

Returning to Mr. Brewer's estimate that 2 per cent. of free oxygen is present in the cylinder even when the products of combustion contain as much as 9 per cent. of CO (see table), I should like to point out that what he really assumes is that more than 10 per cent of the oxygen present in the cylinder does not take part in the combustion, for the oxygen itself only forms about 19% of the cylinder contents.

For the reasons given above, I cannot agree with Mr. Brewer that he is justified in assuming, without any sort of proof, that in the Lamplough engine, 10% of the oxygen in the cylinder never takes part in combustion, hence reducing the calculated value for the loss of charge by about 30%.

It will be noticed that the loss of charge in the case of the Lamplough engine is practically independent of the speed. This fact shows the efficiency of the pump and that there cannot be much wire drawing in the connecting pipes. The loss of charge is, however, so great that probably a smaller pump would be a great improvement, although the power developed might be reduced. The two-cycle petrol engine will, however, hardly seriously compete with the four-cycle engine when additional power is obtained by scavenging with such an expensive medium as petrol vapour."

Mr. Dugald Clerk said that the question of exhaust gases was a somewhat complicated one, and chemical analysis gave, undoubtedly, valuable indications, but it did not do to rely too much upon analysis for the quantitative determination of lost charge. He agreed with Dr. Watson that, in a gas engine where the gas mixed perfectly with the air, the combustion was practically complete at about 1/10th of the forward stroke or perhaps a little further on. But if one happened to be using a weak gas, such as carbonic oxide and hydrogen producer gas, or petrol, or oil, it did not at all follow that the combustion was complete during the whole stroke of the engine, and it did not follow that combustion was completed even in the exhaust pipe. That depended upon the perfection of mixing in the engine.

He had experimented many times with injecting gas into a cylinder after the compression was complete, and under those circumstances it was often found that the thermal efficiency dropped very rapidly, and that the pressure rise for a given number of cubic inches of gas fell below the pressure attained when the gas was thoroughly mixed with the air on the way to the cylinder. The result was that the gas injected into the air after or during compression failed in many cases to find an excess of oxygen in contact with every part of it. The part of the gas mixed with the oxygen of the air often remained localised in the cylinder with an insufficient quantity of oxygen to burn completely at that particular place. The consequence was that, in such a case, they found in the exhaust not only carbonic oxide but large quantities of oxygen also. But, in that case, the carburating or mixing of the gas with the air had been imperfect, and then the combustion might continue throughout the whole stroke and into the exhaust pipe. He had often noticed, in experimenting with a mixture of that kind, that the flame of the explosion lasted a long way into the exhaust pipe. Then they got excess of oxygen and excess of carbonic oxide.

The experiments by him, which Mr. Brewer had given on page 317, were made with a Siddeley-Wolsley 18 horse-power car, after he had acted as one of the judges at the Royal Automobile Club in the testing of the exhaust gases of many cars. There was no doubt that Dr. Watson was right, and part of the trouble was due to the fact that there was pulsation in the exhaust pipe, so that they could never be quite sure that some air did not get into the vessel used for collecting the gases. Dr. Watson used a more reliable method in the laboratory. He collected the gases close up to the exhaust valve in a glass bulb by mercury displacement. In his (Mr. Dugald Clerk's) experiments with his car on the road he used the same arrangement as the Automobile Club. In many of those experiments there were considerable quantities of oxygen, and yet considerable quantities of carbonic oxide, but wherever the oxygen was high the carbonic oxide was low. For example, with the engine unloaded, at 600 revolutions a minute, the oxygen was 10.6 and the carbonic oxide 1.8 per cent. It was quite true in running light, they might have one cylinder firing and one not firing, and, possibly, a disturbance of the analysis might occur in that way.

He agreed with Dr. Watson that, if they had perfect mixture and consequently perfect combustion, the combustion was completed in a very small fraction of a second. Some years ago he made some experiments in which he mixed gas and air perfectly, and then exploded and blew the flame produced through wire gauze. He then found that when the flame cooled down in about one-thirtieth of a second, there was practically complete combustion with a good mixture. But in ordinary gas engines far more than the thirtieth of a second was available in which to complete combustion. About one-fifth second was usually occupied by the power stroke. In a high-speed petrol motor, one sixteenth of a second represented the available time. But he thought that it might be taken that, in the main, combustion was complete very soon after the flame was passed through the mass. He did not think, however, that one could entirely rely upon the chemical composition to give the true value of lost charge by the exhaust, because there were so many disturbing conditions such as he had pointed out. There was, for instance, imperfect combustion due to bad mixture, and other matters. Taking the two-cycle engines such as Mr. Brewer had been experimenting with in most of them, the percentage of exhaust gases left was considerably greater than in four-cycle engines. They must not discharge too much exhaust gas from the cylinders, to avoid the discharge of combustible gases at the same time. To reduce this loss it was necessary to pass a relatively small percentage into the cylinder. That was the reason why the working pressures of two-cycle engines were generally lower than those of the four-cycle, smaller inflammable charges were introduced into the cylinder and larger proportions of exhaust gases were left in it.

It was quite true, as Mr. Brewer said, that one idea of the two-cycle engine was to get advantages as to weight for power ; but there were great difficulties in getting that advantage.

He might mention what he (Mr. Dugald Clerk) did in the early days. He began work on the gas engine in 1876, and his first engine was built in 1877. It was exhibited in 1879 at the Royal Agricultural Societies' Kilburn Show in London. In that engine he had two cylinders, one of which was a pump and the other a motor. The pump cylinder compressed the charge to the full pressure intended for ignition ; and the second cylinder was operated like a steam engine ; at the beginning of the stroke it took in a portion of the charge under pressure from the reservoir into which it was pumped by the first cylinder. That proportion of the stroke was made under a charge pressure of about 70lb. per sq. in. above atmosphere. Then the slide valve cut off, there was a slight drop in the diagram, and ignition was effected by the platinum igniter of which Mr. Brewer spoke. They got, in that way, an impulse at every revolution. The difficulties of this type of engine were two-fold. In the first place, to compress the mixture to the full pressure, the pump cylinder piston and crank had to be as strong as the motor cylinder piston and crank. The second difficulty was that the point of cut-off and the point of ignition had to be extremely close ; otherwise, there would be a fall in the diagram. The consequence was that there was a rather too delicate adjustment between the time of cut-off and the time of ignition. But these matters were overcome, and the engine ran exceedingly well ; yet it did not compete with the Otto, because it had two cylinders as heavy as the Otto and there was practically no weight advantage in it.

After that engine he produced the engine which was known as the Clerk engine. That was in 1880. It was exhibited in the Paris Exhibition in 1881, and gained a silver medal. That engine was on a different principle. It had a cylinder in which there was a piston, and the piston at the out end of the stroke overran ports formed in the sides. The motor piston overran the ports and discharged the exhaust through them. There was ignition, not during the forward stroke, but on the dead centre, the ignition was followed by expansion and at the end of the stroke the pressure fell to atmospheric because of the opening of the ports by the piston. The two-stroke cycle was accomplished by taking the charge of gas and air into an auxiliary cylinder, which he called a displacer. It was a very light cylinder without water-jacket and with a light piston. The advantage of this engine was that it had only one piston, which took the whole load of the explosion and compression pressures. The other piston was very light. He was thus able to realise one of the advantages mentioned by Mr. Brewer, and he was able to get the full mean pressure possible in the Otto cycle, and to get a respectably

economical consumption for those days. In the Otto engine the indicated efficiency was 16 per cent, and he was able to get 17 per cent. indicated efficiency by the use of somewhat higher compression. He calculated that the loss through the exhaust port was something under 10 per cent. This engine was sold in large numbers in England, and it was built in America as well.

The members could quite understand that he felt very pleased indeed to see the two-cycle engine coming up again. There was no one, he believed, more sensible than he was of its disadvantages, and there were several disadvantages which had not been mentioned in the paper. In the two-cycle engine there was an impulse at every revolution, so that there was no intermediate revolution to allow the cylinder to cool down. They had a greater amount of heat to be dissipated for given cylinder dimensions, so that with the two-cycle engine troubles arose more quickly than with the four-cycle, as far as the temperature was concerned. But the thermo-dynamics of the two were quite the same.

The advantages of two-cycle engines were very great, and he quite agreed with Mr. Brewer that there was considerable scope for the application of small engines. Of course, in small engines, such as petrol engines, they had other things to consider. One was the question of balance. If one had a sufficient number of cylinders, there would be no difficulty about balance, but the balance question had to be considered, so that they might be able to show at the end an advantage in using the two-stroke engine. The difficulty of mechanical balancing was well met by the use of the Lamplough arrangement, but the system had its disadvantage by giving one impulse on two pistons at the same moment, as Mr. Brewer had pointed out.

He would like to ask Mr. Brewer whether he knew anything about the working of the Hazelton two-stroke engine. It seemed to him (Mr. Dugald Clerk) impracticable. He could not understand it. Many attempts had been made to use double pistons in the same way, but, as far as he knew, none of them had succeeded. Perhaps Mr. Brewer could inform the meeting whether there were any two-stroke engines of that kind in use.

He had no doubt at all that, by means of persevering and careful study, two-stroke engines might be brought to high efficiencies, and that other great advantages could be attained in small engines with the two-stroke cycle. Messrs. Koerting and Messrs. Mather and Platt had paid great attention to the two-cycle engine, and they had adopted a modified Clerk engine which had given excellent results up to two thousand and three thousand horse-power, and with this engine they had been able to get a thermal efficiency as high as with any four-stroke engine for a given compression. Messrs. Mather and Platt's tests showed 30.6 per cent. indicated thermal efficiency and Prof. Meyer's tests of a two-cycle engine of another type gave as much as 38 per cent.

indicated thermal efficiency, so there seemed to be no reason why, when as much labour had been spent upon the two-stroke engine as had already been devoted to the four-stroke engine, they should not be able to have economical two-cycle engines adapted for all purposes and all sizes as well as four-cycle engines. The signs of the times were very much in that direction, both for large and or small engines.

Mr. Clerk congratulated the author upon his excellent paper.

Mr. W. A. Tookey said that they had listened to a very interesting paper from Mr. Brewer and had enjoyed the description of the early experiments of Mr. Dugald Clerk, who had done so much pioneer work in internal combustion engines generally. When testing two-cycle engines, the speaker had frequently noticed that in any repetition of a test it was almost certain that the results which one would expect to be somewhat similar were in fact very different, and especially so when the speed of the engine rather than the output of power was varied. In his opinion the two-cycle engine was particularly sensitive to the inertia effects set up by the length of piping connections and hitherto he thought, too little attention had been given to this point. The size and extent of exhaust piping undoubtedly had a marked effect in all internal combustion engines upon the mixture entering the cylinder at different loads and at different speeds, and these variations were very noticeable in two-cycle engines.

In the course of a series of tests upon gas engines working in many London factories he had been able to note the performances of ordinary four-cycle gas engines of the same make, of the same cylinder dimensions, and of comparable age, when fitted with piping suitable to the circumstances obtaining in different workshops, and the effect of the length of exhaust pipe—to say nothing of the connections upon the inlet side of the engines—affected the performances of the engines very considerably. It was well known that after the exhaust valve had been opened, the burnt gases in the cylinder rushed with great velocity through the piping leading to the atmosphere. Upon the closing of the valve the continued movement of the gases brought about a lowering of the pressure to below atmospheric under the exhaust valve, and the consequence was the the gases were partially drawn back, giving a pulsating effect two or three times repeated in the case of single-cylinder four-cycle engines. He had been able to obtain indicator diagrams from the exhaust pipes of some engines which clearly showed these pulsations. At certain critical speeds the pulsations were amplified. In a quick running two-cycle engine with the escape of the burnt gases brought about by the passing of a piston across cylinder ports, the effect of the phenomena was likely to be greater than in the case of an ordinary

gas engine provided with a valve and working upon a cycle of operations which allowed one complete stroke of the piston for the purging of the cylinder.

A series of experiments would no doubt enable one to determine the proper length of exhaust pipe that should be fitted to a two-cycle engine so as to give the maximum scavenge to the engine cylinder when working at a certain speed. Unfortunately the two-cycle engine intended for marine and vehicular work must run at varying speeds—in this respect differing materially from the ordinary stationary engine. The author had stated that exhaust ports were a necessity in two-cycle engines, but having regard to the fact that the pulsations already referred to could not be entirely eliminated in practical work and that wear of the piston might establish some connection between the crank chamber or inlet ports with the gases already passed into the exhaust connections, it seemed to the speaker that it would be worth trial to add a mechanically moved valve which would isolate the cylinder from the exhaust connection between the closing and reopening of the ports by the motor piston. He was of the opinion that some such provision would be found of service, particularly in the case of multi-cylinder engines. It would then, he thought, be possible to obtain more uniform carburation generally at any speed, while the effectiveness of the scavenging could probably be further increased by the cooling of the exhaust pipe by water circulation.

He agreed with the author that a considerable amount of work still remained to be done before two-cycle engines could compete with four-cycle engines in general application. Unfortunately experiments were very costly and frequently the experiments were made by those unable to appreciate the points which would bring out the best performances of the engines, while the test conditions were far from being standardised. There was little doubt that if capital were available and those interested possessed patience and perseverance and could, after the successful development of the engine, themselves make use of it in commercial work, the present difficulties would be surmounted and a serious competitor to the four-cycle engine produced. Over and over again in his experience he had come across inventors having good ideas for two-cycle engines lacking the funds to carry out the necessary experiments and unable to interest those who could help financially owing to the absence of a working model. Just recently he had been called upon to give an opinion as to the probable value of an idea for a two-cycle engine which seemed to promise well. At the moment he could give no particulars, but he thought that within the next year or two something would be put upon the market which would be far in advance of the two-cycle engine as they now knew it.

Mr. Alan E. L. Chorlton said that the question of vibration in the exhaust pipes which had been spoken of by Mr. Tookey was certainly a very important thing, but he thought that that gentleman went rather too far in saying that it was of more importance in two-cycle than in four-cycle engines. Mr. Tookey, was doubtless, acquainted with the very large four-cycle German engines, and he would find that in that type of engine when the air and gas were drawn in, vibrations would occur just as readily, or perhaps more so, in the induction pipe than in the exhaust pipe of either type. Moreover, the difficulty was magnified by the fact that two vibrations of air and of gas have to be taken into account, consequently, unless steps were taken, the power of the engine and the regularity of firing would be entirely upset or varied, due to the variation in the mixture from want of agreement in the two vibrations. About five or six years ago the German four-cycle constructors made use of a peculiar valve gear in order to get over the double vibration difficulty. A valve opening allowed air only to enter the cylinder ; then this air was cut off and air and gas valves opened to allowed the mixture to be drawn in. It was not sufficient to allow the air to enter and then to allow the gas to enter. The air had first to be cut off, and then re-admitted to prevent the vibration set up by the inertia of its flow. This was got over in the later engines by having very large receivers. On the other side of the engine, i.e., the exhaust, they had just as great a difficulty with the four-stroke design, for they had to deal with the outlet pipe, in which they got another vibration effect. These difficulties, affecting the maximum output of power, might have been overcome by the people that had tuned up the racing cars at Brooklands, for he knew that very high powers for engine dimensions had been obtained there.

These vibrations in two-cycle gas engines were important only as regards the exhaust, so he had made his experiments with exhausts. At the inlet they charged with a pair of pumps of known proportionate volumes, consequently they had always the same proportion of air and gas in the charge, varied only in pressure by the vibrations in the exhaust. The value of properly controlled vibrations in the exhaust as a scavenging agent for four-cycle engines was shown years ago by Mr. Atkinson of Messrs. Crossleys. In a two-stroke engine it is required to proportion the exhaust pipe in length to step in with the number of revolutions of the engine per minute and the angle of exhaust discharge, in order to get exactly the right effect on the engine itself.

Mr. Dugald Clerk showed on the diagram of his two-cycle engine the exhaust line brought down to the atmospheric line rather too suddenly, and then coincident with that line to the

end of the stroke. In a large engine, if they were to magnify that diagram they would see that it fell below the atmospheric line and jumped up again. In an engine in which the line fell quickly like that and then jumped up again, the pressure through the whole engine and pumps would be raised. He should think that in a small engine it would be very important to secure the correct action of the exhaust and charging cycles, making the various pressures in the pump passages and cylinder properly synchronise at the right periods, and to damp out the vibrations in the exhaust. In the paper there were no diagrams taken of the engine to show if this was so, and therefore, one could not relate the pump to the main cylinder in any way.

In the table of powers required to drive the pump it was not shown how these were affected by power and pressure generated in the cylinder, together with the action of the exhaust. When they had power generated they had perhaps a correspondingly increased load effect on the pump. It was also noticeable that a great deal of petrol was condensed in the passages; the mixture must obviously not be properly mixed on entering the cylinder, and it was quite possible that that accounted for the heavy consumption and loss by unburnt charge in the exhaust. In large engines when properly adjusted they got no combustible matter in the exhaust. He had been dealing with two-cycle engines now for ten years in this country, steadily improving the design, until the running experience was now so good that he thought that they would ultimately become *the* engines.

Mr. L. H. Hounsfield said that he wished to make some enquiries of the author. On page 307 the author mentioned 35 to 40 per cent. loss of heat to the water-jacket, referring both to two-cycle and four-cycle engines. Surely the symmetry of the combustion chamber of most of the two-cycle engines ought to favour the latter as far as the loss of heat was concerned. He knew, of course, that Dr. Watson inferred that the area of the combustion chamber was unimportant. Professor Callendar, however, seemed to think that Dr. Watson had drawn erroneous conclusions from his experiments.* Professor Callendar mentioned 25 per cent. as jacket loss in large four-cycle engines, of which 5 per cent. was during the explosion and the remaining 20 per cent. during the exhaust† the inference being that most of the heat was given up to the jacket while the exhaust was rushing round the exhaust valve pocket. The heat of a gas was more readily given up while the gas was in motion than when it was more or less in stationary contact with the cylinder walls, as during the explosion. To back up that, they had experience of the Franklin car in America. The makers found it necessary, in order to prevent over-heating in this air-

* Discussion on Dr. Watson's paper, at Inst. Auto. Engrs., Dec. 14th, 1910.

† Proceedings of Inst. of Auto. Engrs. Vol. I., p. 284.

cooled four-stroke cycle engine, to put a port exhaust at the end of the stroke, so that the whole of the said 20 per cent. of the heat would not be given up to the exhaust valve and the surrounding cylinder while the exhaust gas was passing out. Of course, the Franklin engine ran particularly cool. He agreed with Mr. Lucas and the last speaker with regard to the simplicity of two-cycle engines. He was extremely interested in two-cycle engines as he wanted to see something simpler for motor cars. But as long as two-cycle engines were of the type in which there were so many parts, he did not think the two-cycle engine worth trying. If two-cycle engines of the type having one or two pistons, crank shaft, and connecting rods as the only working parts, could be made to work satisfactorily, then, he thought, two-cycle engines would have an excellent future.

With regard to the objections to two-cycle engines on page 306, he should like to know whether the author in his experiments had any difficulty in keeping the exhaust clear, or whether the piston carried the oil out of the exhaust port. He should also like to know whether the ports had caused the piston to score, or whether the piston going past the ports had scored the cylinder.

Mr. W. G. Walker said that he had not proposed to make any remarks in connection with the paper, but the author had referred to his fan brake dynamometer. As he had not referred to that machine before in public or written anything about it, he might make a few remarks in connection with it. He had had one sent to the meeting exactly similar to the one with which the author carried out his experiments. The author's experiments were carried out principally with a plate 8½ins. by 11ins., like the one now shown. This was a 60 horse-power dynamometer. It would register the horse-power at 1,000 revolutions a minute from 1 horse-power up to 60 and could be put on various sizes of shafts from ¾in. to 2ins. It would be seen that the plates were calibrated for different radii, so that all that had to be done was to take the number of revolutions of the motor cubed and multiply them by a constant; or if they took the number of revolutions, they simply had to refer to a chart and read the brake horse-power directly off the chart. He had been making a considerable number of sizes. The smallest size that he had made was one giving 5 horse-power at about 15,000 revolutions a minute; that was for testing single wheel steam turbines. The size of the plate, in order to give 5 horse-power at 15,000 revolutions a minute, was about 1 square inch, with a radius of about 3½ins. The horse-power absorbed was enormous when they got to high speeds. He had several slow speed dynamometers now, giving as much as 300 horse-power at 150 revolutions a minute. The great difficulty was

in calibrating the dynamometers. They had been calibrated by electric motors. All the sizes up to 60 h.p. had been tested against Prony brakes on electric motors. The larger powers were calibrated by electric motors only, and by electrical measurements, allowance being made for the various electrical and mechanical losses in the motors.

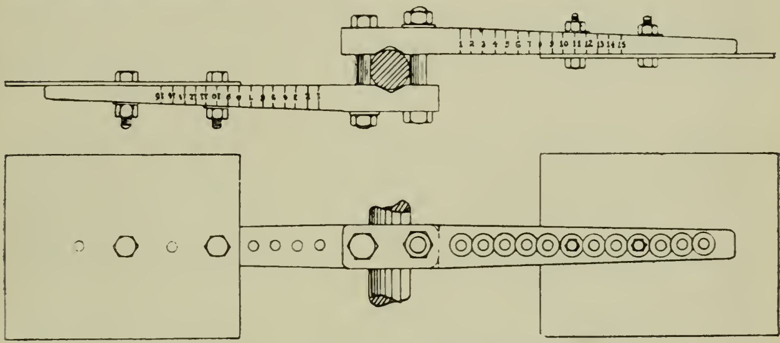


Fig. 10. WALKER DYNAMOMETER.

Mr. T. Welsh wished to ask the author, with regard to the Lamplough engine, taking the time when ignition might occur, one piston being at the top of the stroke and the other one not quite up to the top, whether this might not produce a bad effect owing to expansion not taking place sufficiently rapidly after ignition ?

With regard to the irregular texture of the mixture which was taken in the high speed petrol motors, more particularly the multi-cylinder engines, supposing that the carburetter would develop a mixture which was of a perfectly regular texture under all conditions, he did not think that any carburetter had yet attained to this ideal. And supposing the mixture would start in the inlet pipe in a perfect condition, it would be subjected to a lot of stratification and irregularities before it reached the engine cylinder, and this would quite account for irregular distribution in the cylinder. In a curved pipe, for instance, any of the heavier particles would tend to be thrown towards the outside. The sprayed petrol, being very much heavier than the air, would be thrown to the outside of the curve, and, in a pipe which branched from the carburetter and led along to the four cylinders, the two centre cylinders, as he had invariably found, got a much weaker charge than the two outside cylinders, because the gas was drawn into these inside cylinders ; but the sprayed petrol was much heavier and could not follow round the curve in time. It was thrown to the outer ends, and always caused the mixture to be stronger in the outer cylinders.

With regard to Mr. Lucas's remarks on the gauze for damping down the back firing, he would ask did not combustion take

place on the cylinder side of the gauze in an engine of that description, even though it might not manifest itself by back firing through the carburetter ?

He had had some experience in back firing even with a four-cycle engine. Supposing that one cylinder was missing fire, discharging a nice mixture into the exhaust pipe, it was fired by another charge which was already being exhausted, probably in a very hot state, and fired back through this cylinder, which was exhausting the unfired charge, and right back to the carburetter.

Mr. L. T. Godfrey Evans said that he had not had so much practical experience of the modern type of internal combustion two-cycle engines as some of those present, although he might claim to have been one of the first to have had practical experience in two-cycle gas engines—he referred to the "Beechey two-cycle gas engine" made by Fawcett Preston & Co., of Liverpool, where he was a designer at one time. He was concerned in the success of an engine which was peculiarly interesting on account of its having a twin-cylinder with communications at the top, middle and bottom, and two pistons working in opposite directions in each twin cylinder.

Referring to the illustration on page 329, the bottom pistons (B) worked through connecting rods (C) which were coupled directly to the centre pin of the crank shaft (D), whilst the top pistons (E), were rigidly secured to tail rods to the cross-head (S) which formed the piston of a large air pump (F) shewn above the twin cylinders (A). Motion from the cross-head was transmitted to the crank shaft by means of two rods working in guides and the outside connecting rods (K). The crank case was not used and was very small, so that the total height of the engine was no greater than that of other two-cycle engines of similar horse-power. The action of the engine, the fuel and air being under constant pressure, was that the feed worked automatically according to the work required—the fuel from a supply tank and the air from an air-pump (F). These were thoroughly mixed in an apparatus (U) and then admitted to above the top pistons during the period of their descent, and on the return stroke this rich mixture was compressed. Just before the conclusion of this outward or return stroke, the rich mixture was forced through the side passage into the cylinders between the four pistons, where it was further diluted by the air left after clearing the cylinders of the residue of burnt gases from the previous combustion. A wall of air was provided in the top space (B) so that on the passage being opened for the rich mixture to be forced into the middle, the flame would not ignite the incoming charge. On the inward stroke of the four pistons the diluted mixture was compressed in the usual way and fired by

the sparking plug, the pistons then being forced outward until they uncovered the outlet ports (P) in four different places simultaneously. Air under pressure was admitted from special ports (O), which effectually drove out the burnt gases. Some air might escape into the exhaust pipe, the residual air diluting the incoming rich mixture to form a duly proportioned explosive mixture to be compressed and fired, as already stated. It would be noticed that no ports were exposed to the intense heat of the gases.

The engine had been freely tested for some months past and although these tests were satisfactory, applications for patents in respect of further improvements were pending. Instead of the two connecting rods (C) as shewn, there would be only one, on which an "off-set" was placed and to which the other connecting rod joined, with the result that this "off-set" imparted a slightly increased stroke to its piston, so that on the firing, the piston (B) moved for a fractional part of its stroke against the pressure, which of course was favourable. The manner of automatically regulating the supply under pressure was the subject of a provisional patent application. As regards the air-pumps (G) the piston was perforated with holes, which were covered with a disc (S), also perforated, but its holes are staggered in relation to those in the piston. This disc worked on and off its seat by its momentum—the air being free to enter the pump (G) during the rising stroke of the piston and trapped on the return stroke, due to the piston overtaking the disc and so closing the apertures—the air being then forced through the fuel chamber into the top of the working cylinders.

Comparisons of this system of mixing petrol under pressure and air (also under pressure) with engines having carburetters—the principle of which was that air and petrol were drawn through them by the force (atmospheric pressure) of induction of the engine piston—was simply out of the question so far as actual filling of the cylinder with the mixture was concerned. This amount, even with the four-stroke cycle, varied with the velocity of the piston from 80% at slow speeds to less than 30% at excessively high velocities. At no period of the experimental tests was a satisfactory compression obtained, but varied from 16lb. to a maximum of 40lb. per sq. in., yet notwithstanding this low compression, the explosive pressure exceeded 385lb. per sq. in., consequently, no reliable data could be taken as to consumption of petrol per horse-power. This high pressure was no doubt the result of the excellent system of scavenging and the freedom from "gas bound" residual burnt gas, and further, the thorough mixture of the gas and air due to superpressure. He did not know what others thought the pressure should be in order to fill the cylinder at various piston speeds, as it had been stated by one that 5lb. per sq. in. was ample, although

he thought that from 15 to 20lb. at the very least was needful for a two-cycle engine, if the cylinder was to be filled at high piston velocities. In such cases, and with proper scavenging there would be little chance of carbon monoxide finding its way into the exhaust pipe, as owing to the carbon and air being brought into closer contact by a higher pressure, complete combustion must be more rapid in the initial part of the stroke than in the ordinary way ; consequently, oxygen present in the air for want of carbon to be taken up could escape with the carbonic gas into the atmosphere.

In this engine the air and fuel had a continuously forward movement from their contact at the mixing chamber until their exit from the engine as spent gas, and with equal cylinder dimensions the working parts could be made very much lighter and more efficient compared with a four-cycle engine, there being one impulse at each revolution instead of at every other revolutions. The volume of the air or fuel might be varied to suit varying loads—the one increased or the other decreased. The chief points claimed for this engine, were few parts (less than 100 as against about 500 in the Gnome engine), steadiness, simplicity, lightness, direct central action, slow piston speed, quick exit of exhaust gas, low prime cost and maintenance, great torque at low engine speeds, perfect lubrication, and adaptability for petrol or paraffin.

Mr. C. C. B. Morris said that he was not an expert on the two-cycle engine, but that engine was of considerable moment to the London Fire Brigade. They were sometimes accused of progressing very slowly in the matter of replacing their horses with motors. He could assure the meeting that as yet they had no machine satisfactory in every respect for their purpose. They had to face the question of excessive weight at a fairly high speed, and if, as Mr. Brewer said, engineers would be able to design shortly a satisfactory two-cycle engine developing a given horse-power with half the weight, the Fire Brigade would be one of the first bodies to realise its advantages. The question of weight was one of importance, mainly on the score of non-skids. This might not appeal to the meeting as it did to the Brigade. They had machines running at present having a weight of three tons five cwt. on the rear axle, and one ton six cwt. on the front axle, and it would be impossible to run them at any reasonable speed unless they had non-skids fitted. There was at present no efficient non-skid for solid tyres which gave satisfactory results without being very expensive to maintain. They were in communication with a well known maker of pneumatic tyres, and hoped shortly to experiment, but he very much doubted whether such experiments would be successful with the weights given. He might mention that he was

interested personally in the matter of paraffin carburettors. He thought that the two-cycle engine appeared to be more suitable for the combustion of paraffin than the Otto cycle engine, and he should like to ask Mr. Brewer whether he had any experiments conducted on the two-cycle engine with paraffin.

Mr. E. H. Micklewood said that the two-cycle engine was one to which he had given very great attention for the past eight years, and he had reasoned that, if anyone approached the problem with the idea of getting further into it and improving the engine, what he had first to do was to realise the true inwardness of the problem, and to find out what had been done, the lines along which success had been achieved and the lines along which failure had resulted. Let them realise, if they could, why success followed certain processes and why failure followed others. In that spirit he had approached the problem of getting twice as many impulses from the internal combustion engine as were ordinarily got from the four-stroke cycle engine.

The first thing that they had to realise was that the internal combustion engine was essentially an air pump, and that the four-cycle example of it acted alternately as a pump and as an engine. As a pump it drew in a combustible charge and compressed it ; and as an engine it fired the charge and got rid of the products of combustion. As far as he could realise the problem of the two-stroke cycle it amounted to this—that all that they attempted to do, and what they were trying to do all the time, was to get rid of the pump action and replace it with an engine action so that in the same cylinder they got two impulses instead of one. But it was useless to do this unless they could get into the cylinder as good a charge as the ordinary four-cycle provided. Further than this, it was of no use to do it, if they had to introduce many complications. They were all of them willing to spend fifteen shillings to get one pound, but they were better pleased if they had to spend only five shillings to get the pound. But it was not a particle of good to spend twenty or twenty-five shillings to bring in a pound, and as far as results went no engine of the two-cycle variety produced up to now had practically returned more than was spent on it. Mr. Brewer alluded in his paper to his (Mr. Micklewood's) engine which would be found on Plate II. and was described on pages 331 and 332, and he pointed out that in a measure it appeared to attain very much the same ends as the Koerting engine. If they referred to the Koerting engine they would find that it had a number of side pumps, and he thought Mr. Brewer was absolutely right when he said that he (Mr. Micklewood) obtained the same end. They would notice that the engine was essentially a cylinder engine of two dimensions with a piston to correspond, and with the piston sliding over a fixed sleeve. It was nothing

in the world but a simple flanged pipe. By that means, however, with every function in perfect order he obtained a two-stroke engine in which he got a good scavenge. He got a very good induction stroke into the upper annular chamber. He, in fact, converted the working end of the cylinder into an engine on every stroke, coupled with a double-ended pump at the bottom ; and also he got a super-atmospheric engine, although he rather thought that Mr. Brewer seemed to doubt that somewhat, because the words " super-atmospheric " were in quotation marks. It was quite clear, at any rate, from his (Mr. Micklewood's) point of view that the engine was super-atmospheric, and perhaps it would be as well for him to define exactly what he meant by that, because he and Mr. Brewer might be looking at the matter from different points of view. The meaning that he attached to 'super-atmospheric' was that there was, in the chamber in which combustion and expansion took place at the moment of ignition, a denser charge than that which it would contain as the result of induction under ordinary atmospheric conditions. The whole problem of the internal combustion engine was summed up practically in the following paragraph in Mr. Brewer's book. " The Motor Car," published by Crosby, Lockwood and Co.: " When the piston is at the outward end of its stroke the object of the engineer is to fill the cylinder with an explosive mixture of as great a weight per unit volume as possible. This means that the pressure must be as high as possible and the temperature as low as practical limits will permit. The efficiency of the system depends upon the maximum possible amount of fuel being efficiently burnt in unit time." That was a complete epitome of the problem before the combustion engine engineer, and he had often thought that it was what they had got to work up to. They had to get the greatest possible charge and use it as often as possible ; in other words, to burn efficiently the highest possible amount of fuel in unit time. Therefore, in attaining a fully charged and scavenged two-cycle engine he should say that by that means a very big step in the right direction had been taken, and if, in addition, super-atmospheric conditions were reached, and the means were simple enough and mechanical enough then a very big step indeed had been taken. It was perhaps for others than himself to say how far his solution of attaining a definite scavenge apart from the crank case helped to take them upon the road to a solution. If they studied that engine they would perhaps consider with him that it was one which could be built of any dimensions whatever and, therefore, if it would bear the test of full examination, as he thought it would—for he had made four, and the last one had been running very well indeed for some months—then he had gone a long way towards solving the difficulties which beset gas engineers dealing with large units.

In a very small internal combustion engine there was inefficiency because the fuel burnt was out of proportion to the radiation, but as they went on increasing the size they gradually came to the point of greatest economy because the two fairly balanced one another. When, however, they got to the very big engine they came to difficulties because the core of heat contained in the combustion chamber was so enormous that water-cooled pistons became a necessity. If, however, they could get a two-cycle engine which would be as good stroke for stroke, they would at any rate cut the difficulties of the big gas engineers in two. But if in addition to that they could have a super-atmospheric charge they would have gone a long way towards still further reducing the difficulty of the big gas engineers. It had been shown by Mr. Dugald Clerk that, as a result of super-atmospheric pressure, they got a reduced maximum pressure, viz., less strain on crank-pin and bearings, but an increased mean pressure. That was what they were looking for. They also got—and this was where the advantage came in—an enormously reduced maximum temperature and that, again, helped them in a difficulty which the two-cycle engine might be supposed to introduce, inasmuch as they fired twice as often as usual. If therefore they had an engine on sufficiently simple and correct lines mechanically, which efficiently fired twice as often as usual and, due to its super-atmospheric character, gave an increased mean pressure with greatly reduced maximum temperatures, then they had made a considerable advance.

He ventured definitely to question the conclusion set out by Mr. Brewer on page 324, that very much still remained to be done to the two-cycle engine and that it would be a long time before the present high state of efficiency of the four-cycle engine was either reached or exceeded.

Mr. R. Lucas said that one gentleman in referring to back firing through wire gauze said that surely the charge would fire on the cylinder side of the gauze. Certainly that would be so. The only tendency to back firing was when the engine was running very light indeed, and, therefore, there was very little gas going through the cylinders.

Mr. H. R. Ricardo said that there was one point which had not been mentioned, and that was the question of flexibility, both of torque and engine speed. It was in this respect that two-cycle engines in general, and he thought, the Dolphin engine in particular, scored so heavily over the four-cycle type. In the Dolphin engine the head of the cylinder was provided with a small pocket into which the fresh charge from the displacer cylinder first entered. The functions of this pocket were two-fold (A) to ensure that, however light the load, there was always

a small quantity of fresh gas in the pocket in close proximity to the igniter, so that regular ignition might take place on the lightest loads; (B) to collect the gases and damp out any turbulence that might be set up by the automatic valve, with the result that they passed into the cylinder proper in the form of a solid cone, driving the exhaust gases before them. Experiments with glass tubes and smoke had shown that with a suitable angle of cone, and size and shape of pocket, very little turbulence or mixing with the exhaust gases need occur.

The result of the use of this pocket was that a two-cylinder engine would run perfectly steadily at 130-140 r.p.m. on no load, without missing on either cylinder, and when driving a car on top speed he had covered 1 mile at Brooklands at a speed of 37 miles per hour without a single misfire with the same gear; the maximum speed was 47 m.p.h., the engine revolutions being 121 and 1,530 r.p.m. With the same gear ratio the car could be driven all day in London, and to Southampton and back without change of gear.

The question of the proportion of live gases lost through the exhaust ports was a difficult one to investigate. Both the author and Professor Watson had made analyses of the exhaust gases, but even when this was done it was difficult to discriminate between loss of charge and incomplete combustion. He had not yet had an opportunity of taking any exhaust gas analyses from a Dolphin engine, but a rough idea of the loss through the ports could be gained in this way. A single cylinder engine had been tested with a number of different displacer cylinders and pistons, all other conditions remaining the same. It had been found that when the volume swept by the displacer piston was equal to that swept by the working piston, the fuel consumption amounted to 0.9 pints per B.H.P. hour. With larger displacer cylinders the consumption per B.H.P. hour fell steadily, reaching a minimum when the volume swept by the displacer was 30% greater. The B.H.P. also increased in direct proportion to the capacity of the displacer cylinder. The inference that might be drawn from this was, he thought, quite clear. The greater value of ηP in the Dolphin engine was, of course, due to the greater proportionate capacity of the displacer cylinder.

He could not help criticising the use of a receiver in the Lamplough engine. This must increase the work done by the displacer piston to a very great extent. In the Dolphin engine he had endeavoured to reduce pump losses to a minimum by so coupling the pump piston that it performed practically the whole of its effective pumping stroke while the exhaust ports were uncovered. The author did not give any figures of the proportion of power absorbed by the displacer, so that it was not possible to make any comparisons. In the Dolphin engine it generally

varied from 7.5% to 15%, according to the size and speed of the engine, and the condition of the exhaust.

Several speakers had drawn attention to the influence of exhaust pipes on the running of two-cycle engines. In all exhaust pipes, pulsations were set up to a greater or lesser extent. In constant speed engines these pulsations could and might be made use of for scavenging the exhaust and relieving the displacer pistons, but it was obvious that for that purpose the engine must run in phase with the pulsations—a perfectly possible condition. In multiple cylinder engines as used on motor-cars, he had found these pulsations very troublesome, as at any speed one cylinder might get into phase and another out of phase, causing irregular running, unless separate exhaust pipes were fitted to each cylinder. He had up to the present found it the best policy to use a silencer offering considerable back pressure, say 2 lb. per sq. in., thus increased the work done by the displacers some 2 or 3%, but on the other hand it prevented turbulence. The tests on a two-cylinder Dolphin engine given on page 313 had been taken under these conditions. This engine had cylinders $3\frac{3}{4}$in. bore, 5in. stroke, while the displacers were $4\frac{3}{4}$in. bore, 4in. stroke. He felt that he must apologise for introducing the name "Dolphin" so often, but his experience lately had been very much confined to this engine.

Mr. L. H. Hounsfield called attention to a misnomer which had caused a little misunderstanding. He referred to the term "back firing" which had been used by many of the speakers. Among motormen "back firing" was, he thought, always used for an explosion with premature ignition accompanied by a reversal of the engine.

Mr. Dugald Clerk said that among gas engine makers back firing was the very opposite.

Mr. Hounsfield said that that was what he was going to remark.

Reply.

Mr. R. W. A. Brewer, in reply to the discussion, said that he would reply briefly as the hour was so late. He thought that they would all agree that the discussion had brought out some very interesting points. He must thank the meeting very much for the kind way in which the speakers had put their knowledge at the disposal of the meeting, because engineers were very much disposed to keep to themselves everything that they found out.

The fact was that a problem which eventually resolved itself as having a very simple solution was often arrived at by

means which were rather complex. Some of the speakers had rather made a point of the complex way in which some of the results had been obtained, not necessarily in his case but in the case of other investigators. But in the present state of the comparative infancy of the subject he did not think that engineers should be blamed for using rather complicated and expensive means in order to investigate certain problems, for he found that it was very much easier to eliminate unnecessary parts of machinery than to elaborate what was originally a fairly simple piece of mechanism. They might be excused for going into complications in order to make measurements and arrive at conclusions more easily than they would have done if they had gone by somewhat more simple paths.

He wanted to mention the question of exhaust pipes because it was a point of extreme importance and interest. They all remembered, of course, what Mr. Atkinson did years ago. He (Mr. Brewer) believed that he was correct in saying that Mr. Atkinson specified that the exhaust pipe in the engines which were used then were to be 50ft. long.

Mr. Dugald Clerk—Sixty or seventy feet.

Mr. Brewer (continuing) said that he believed that it was according to the wave length. He saw many of Mr. Atkinson's installations years ago, when this arrangement struck him as being futile in some cases where, instead of the exhaust pipe being straight, considerable eddies were set up by putting into the exhaust pipe complicated bends backwards and forwards, which he thought would probably damp out any good ejector effect that would otherwise be obtained.

There was one point which was very evident and interesting to users of high-speed engines who wished to get rid of the exhaust and that was the length and shape and the contour generally of the exhaust pipe, and on the track they could increase their speed very considerably by making the exhaust pipe of the right shape and length. They knew that there was the curious suction at the end of an exhaust pipe when the engine was running slowly, but if they could take advantage of the pulsations of the exhaust gases in a fairly scientific way they could obtain the most noticeable advantage by the scavenging effect which one exhaust pipe, suitably arranged in the proximity of another, would produce. Of course, the exhaust pipe must be designed with some idea of dimension, and of the diameter and length and the arrangement of the several pipes with regard to each other, whatever their number. Personally he used a pipe, which was a rather common form, where four simple bends came down into a tube of a certain size and the ends of those bends came together at one point, entering the manifold pipe parallel to one another

with their several ends in close proximity. Probably there was a better arrangement than that, but he found that when the size was very carefully thought out the arrangement gave very good results indeed and that practically no pulsations were perceptible in the pipes.

There was one query which caused him to think and that was about the cushioning of the walls with inert gas. He believed that Mr. Lucas raised the point when he said that when an engine was running light and there was a large amount of inert gas, a small amount of carburetted mixture was admitted. The amount of heat transmitted to the walls would be less in proportion by reason of the cushioning of the inert gas round the cylinder walls. That was a curious point and he should like to think more about it.

This brought him to a misconception which was mentioned by one speaker with regard to Mr. Dugald Clerk's super-compression engine. He believed that the super-compression was produced by pumping in inert gas and not fresh air.

Mr. Dugald Clerk (interposing) said that the air was super-compressed, and added to the charge, bringing it up to about 3 lb. per sq. in. above atmosphere. Then he had two other engines in which the exhaust gases were discharged into a chamber increasing the pressure. They were cooled and then carried back to the cylinder and they raised the pressure again to about 3 lb. per sq. in. Very good effects were obtained that way.

The Author—May I ask whether there was anything against the super-compression of the pure air.

Mr. Dugald Clerk—The only thing was that one had to perform work on the air in order to get it into the cylinder About 5 lb. per sq. in. out of the 30 lb. at which the exhaust was released to the receiver was dropped and the exhaust gases entered with the exhaust pressure. Then there was no work to do.

The Author—In that case, had you always 5 lb. back pressure on the exhaust ?

Mr. Dugald Clerk—No ; before the exhaust valve was opened there was a port overrun at the end of the cylinder, which opened into a chamber, and that was just at the top of the exhaust where the pressure was falling. It went into the port and one got it without any back pressure whatever.

The Author—I wanted to be clear on that point, because it has some bearing on the remarks of one of the speakers. Continuing his reply, the author said that Mr. Welsh had raised a

question which he thought was outside the scope of the paper, although the paper had touched upon the difficulty of the carburation when the carburetted mixture was submitted to a tortuous path in pumping. He had found that in rotary pumps there was a very considerable precipitation of the liquid in the pumping apparatus. Of course one very frequently found in induction pipes with bends that there was a precipitation of liquids, but that question was very large and it was one which he was not prepared to go into just now.

With regard to Mr. Hounsfield's remarks, they all knew that with two-cycle engines there was considerable difficulty in lubricating. In some of the engines that was not very great, but generally one was brought up against the lubrication question in two-cycle work. It was generally agreed, he thought, that an engine in which the exhaust ports were cut in the cylinder sides was a very difficult one to lubricate economically.

The Author supplemented his reply by the following written communication :—

The criticisms which Dr. Watson made in his written contribution have been dealt with to some extent by Mr. Dugald Clerk in his remarks, and I am in agreement with this latter gentleman in my supposition that the presence of free oxygen together with carbon monoxide in the exhaust is due to imperfect carburation and not to leakages on the suction side or imperfections in the method of sampling. The samples were taken and the analyses made by a chemist who had considerable experience in this work. It was inconvenient to take the samples in close proximity to the exhaust valves, but the sampling tube was teed off the exhaust pipe about 4ft. from this point and a joint made to exclude air. The exhaust pipe itself was about 30ft. long to the silencer and thence carried up on the roof of the test shop and horizontally, altogether about 50ft. more.

As the engine was a new one and carefully made, and every care was taken with the piping joints, it did not seem possible for air to leak in through the inlet side, and of course there were no tappets or valve spindles. It would appear from other speakers' remarks that the pump capacity was not so much greater than the cylinder capacity as are the pumps in other types of two-stroke engines ; for instance, it was mentioned that in the Dolphin engine the pump capacity was 30% greater than the cylinder capacity as compared with 15% in the Lamplough engine. It must be distinctly understood that this engine is in no way held up as a model of perfection in two-stroke engine work, as in reality it is only a four-stroke engine operating in two stages.

Mr. Dugald Clerk showed that where the fuel was admitted in a gaseous form a more perfect intermingling with the air is

possible and therefore combustion is complete at 10% of the working stroke. In the case of liquid fuel, however, this is scarcely conceivable, in spite of the development of the modern carburettor, and it is reasonable to suppose that, particularly in cases where a large amount of inert gas is present in the cylinder, combustion is considerably retarded.

Pulsations in the exhaust pipe are naturally quite noticeable at slow speeds of revolution, but in the tests given in the paper in Table 1 it will be seen that all the power tests were at speeds of over 1,000 r.p.m., the actual maximum speed attained when the car was on Brooklands track being 2,100 r.p.m. At these high engine speeds certain difficulties did occur, one was that the engine would run perfectly for a distance of two miles, and then the power would suddenly fall away till the engine practically stopped. In some cases the engine would completely stop but would restart again immediately when turned by hand. Something similar to this was mentioned in the discussion and was attributed to pulsations in the exhaust and inlet pipes, but it was cured in this case by a slight alteration to the thin bronze discs interposed between the pump and the mixture receiver. The receiver was necessary in this type of engine in order to obtain perfect balancing.

Mr. Clerk referred to the difficulty of balancing some types of two-stroke engines when the pump cranks were at right angles to the power cranks, as in the Dolphin. The whole object of the pumps is to take advantage of the fact that the lighter pumping pressures only necessitated the use of very light reciprocating parts as compared with those required for the working cylinder parts. Hence these parts must be arranged within the engine so as to balance out in every direction.

In the Lamplough engine with the cranks set in the ordinary way, one set of pumping mechanism, consisting of the pumping piston with its external sliding sleeve and two connecting rods, is exactly balanced to a pair of power pistons with their connecting rods, both as regards dead weight and the weight of each end of the combination when laid horizontally. In spite of the comparatively large weight of the reciprocating mass, however, a working speed as before mentioned up to 2,100 r.p.m. was maintained on the track during the three meetings in which the author drove this engine. Other difficulties which occurred were at first due to the ends of the sparking plugs melting, and after several trials suitable Pognon Hobson plugs were employed with perfect success.

Mr. Tookey thought that the results of the tests were not clearly tabulated, but the figures given are a synopsis of numbers of tests showing the results arrived at during different periods of the investigations, arranged generally as the horse-power increased. It was interesting to note that at one time the

horse-power remained fairly constant between 12 and 12.5, practically independent of engine speed above 1,200 r.p.m., and the author was for many days somewhat puzzled as to the reason of this. This difficulty was eventually overcome.

Mr. Lucas's remarks with regard to admitting the lubricating oil through the carburetter were of considerable interest, and it will be remembered that practically the same system is adopted in the Gnome engine, where, although the castor oil used in this case does not actually pass through the carburetter orifice, it enters the crank chamber through the hollow crankshaft along with the carburated air. Mr. Lucas made a special point of backfiring, but this trouble did not occur on any occasion with the Lamplough engine, though there was some trouble at one time with regard to pre-ignition. When pre-ignition started on the test bench, the engine slowed down and eventually stopped, so the compression pressure was reduced from 88 lb. per sq. in. as tested by the Okill instrument (the engine being driven by a belt) to 80 lb. per sq. in.

Mr. Chorlton's remarks with regard to pulsations in the inlet and exhaust pipes were of great interest, and there was a certain amount of pressure variation in the Lamplough engine receivers, but owing to the high speed of the engine and the capacity of the receiver this did not make any perceptible effect upon the engine working. Mr. Chorlton suggested that there might be some loss on account of the presence of unconsumed liquid fuel, but the reference made in the paper to the presence of the liquid was in the case of another type of engine employing a rotary blower. No liquid was found in this particular engine. Mr. Hounsfield referred to the loss of heat to the water jackets, and Professor Callender's deductions to the effect that in valve engines the great loss occurred in the vicinity of the exhaust valve as the gases escaped.

Mr. Dugald Clerk pointed out that the thermo-dynamics of the four-stroke and two-stroke engines were approximately identical, and it may therefore be assumed that heat is given up to the water in the vicinity of the cylinder wall ports to approximately the same extent in this type of engine as in a valve engine.

Mr. Welsh considered that the position of the pistons at the point of firing was such as would not give satisfactory results, for one piston had not yet reached the top of its stroke when the other piston had commenced to travel downwards. Fig. 3 in the paper shows a diagram of piston travel and from it will be seen that ignition takes place at practically constant volume, as the two pistons are moving in opposite directions. Furthermore, if a thrust diagram be set out it will be seen that the error is very slight owing to the difference in the obliquity of the connecting rods. With regard to any irregularity in the

flow of the gases through the carburettor this is negligible at the high speed at which this type of engine works.

Mr. Godfrey Evans remarked on the difficulty of filling the cylinders with explosive mixture at high speeds, but on reference to the table on page 320 of the paper, calculations based on anemometer observations show that a very satisfactory percentage of the cylinder is filled with fresh mixture. In studying this table it must be borne in mind that the pump capacity is greater than the cylinder capacity, as explained on page 318 of the paper.

Mr. Morris suggested that the two-cycle engine was eminently suitable for use with paraffin as a fuel, and this fuel has been tried in the Lamplough engine, but the tests have not been carried out at sufficient length to enable satisfactory figures to be given. In passing, it may be of interest to note that the author made some fuel consumption tests of this engine fitted to a taxicab chassis and loaded up with 5 cwt. of ballast, over a measured course of 10 miles in London traffic. The conditions were that this course had to occupy one hour, and the fuel consumption was to be at the rate of 20 m.p.g. These conditions were those of the regular test employed by one of the largest taxicab companies in London, and on the two occasions when the tests were made, they were complied with in every respect.

Mr. Micklewood's quotation from the author's little book on "The Motor Car" appeared to be very appropriate, and it is interesting to note that designers of two-stroke engines are in many cases fully alive to the work which other experimenters are carrying out.

Mr. Ricardo gave some interesting figures with regard to the Dolphin engine. With regard to slow running, the Lamplough engine will turn round at about 180 r.p.m. under normal conditions, but when a vent cock on the receivers is opened this speed can be very much reduced to somewhere in the neighbourhood of 120 r.p.m.

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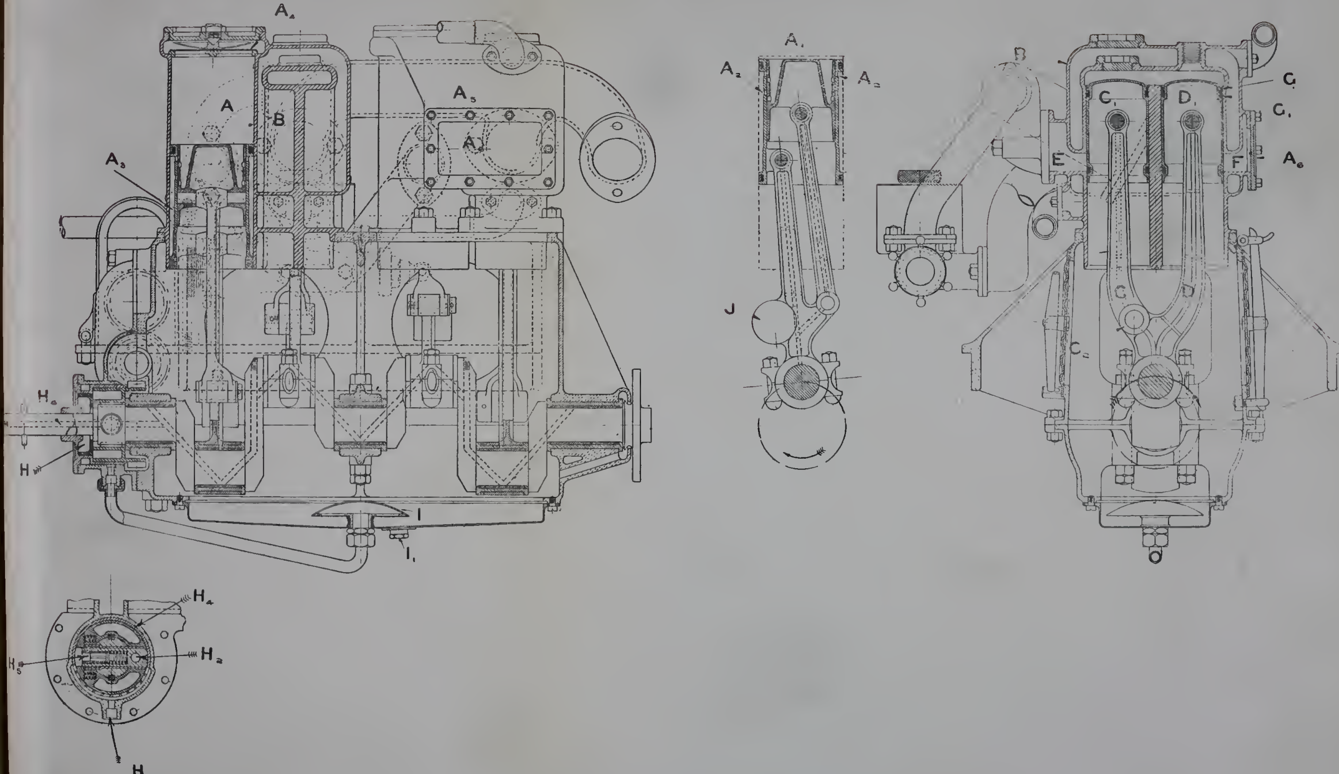
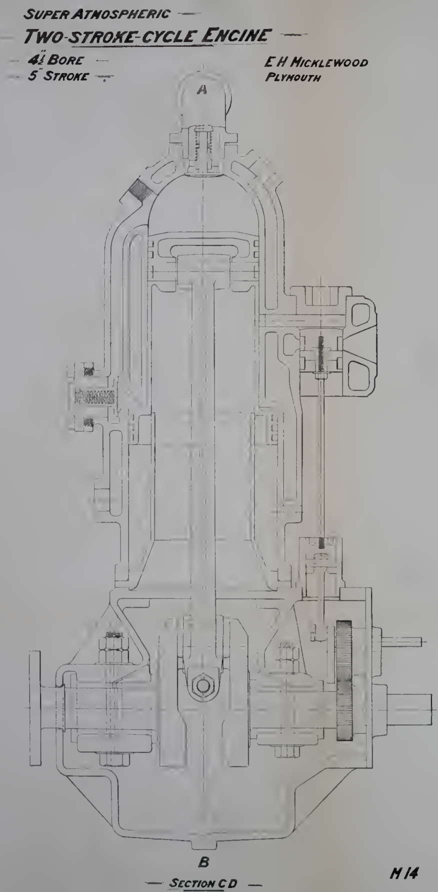
November, 1911.



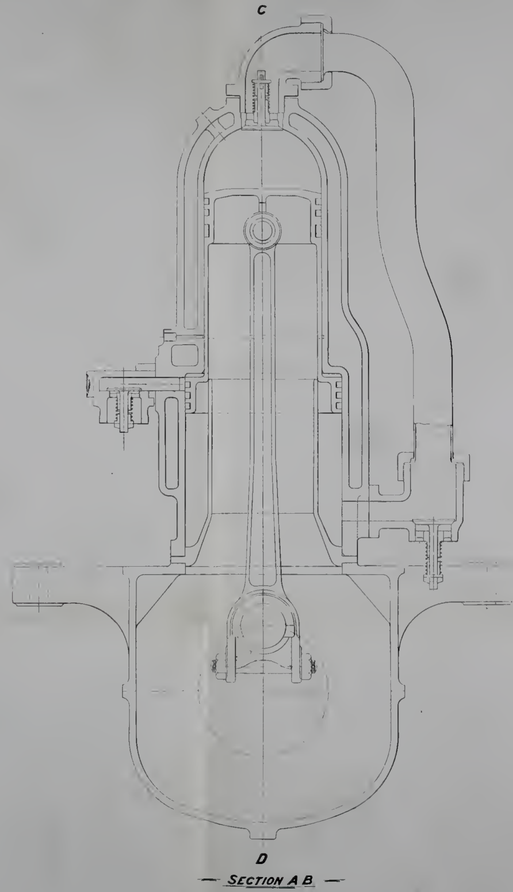
THE LAMPLOUGH ENGINE "MULTI-TWO."

JOURNAL OF THE SOCIETY OF ENGINEERS (INCORPORATED).
November, 1911.

PLATE II.



MICKLEWOOD'S SUPER-ATMOSPHERIC ENGINE.



CROSS SECTION OF MICKLEWOOD'S ENGINE.

Discussion on Mr. R. W. A. Brewer's Paper— "TWO-STROKE CYCLE ENGINES."

The following report of part of the discussion was received too late for insertion in the last issue of the Journal :—

Mr. Ralph Lucas said that on some points his opinions differed from those of the author. Directly the two-stroke cycle engine was complicated with a pump cylinder, valves, etc., it was far better to leave it alone, and keep to their old tried friend the four-cycle engine. However, the difficulties met with in the two-cycle engine might be overcome without these complications. He would take some points singly.

(1) The escape of gas from the exhaust port, which prevented full advantage being taken of the extra power obtainable by an explosion at every revolution, and which gave bad economy. He agreed with the author that this was easily overcome by the use of a U cylinder.

(2) The tendency for the incoming charge to be ignited. The American engineers had entirely surmounted this difficulty by the use of screens of various kinds, the underlying principle of which was some device for drawing the heat away from the screen.

As long ago as 1908 an engine of $5\frac{1}{4}$in. bore and $5\frac{1}{2}$in. stroke, with a U-shaped cylinder, giving 40 H.P. on the brake, gave 31 ton-miles to the gallon in an official R.A.C. test. He thought that these figures were satisfactory enough to show that the two-cycle U-shaped cylinder engine was worth going on with.

There was one other point he would like to mention in connection with two-cycle engines of the crank-case compression type, and that was lubrication. On a recent visit to America he had found that nearly all the two-cycle engines, both in boats and motor cars, were lubricated by mixing oil with petrol in the tank, and this system of lubrication was far ahead of all others, both for simplicity and reliability.

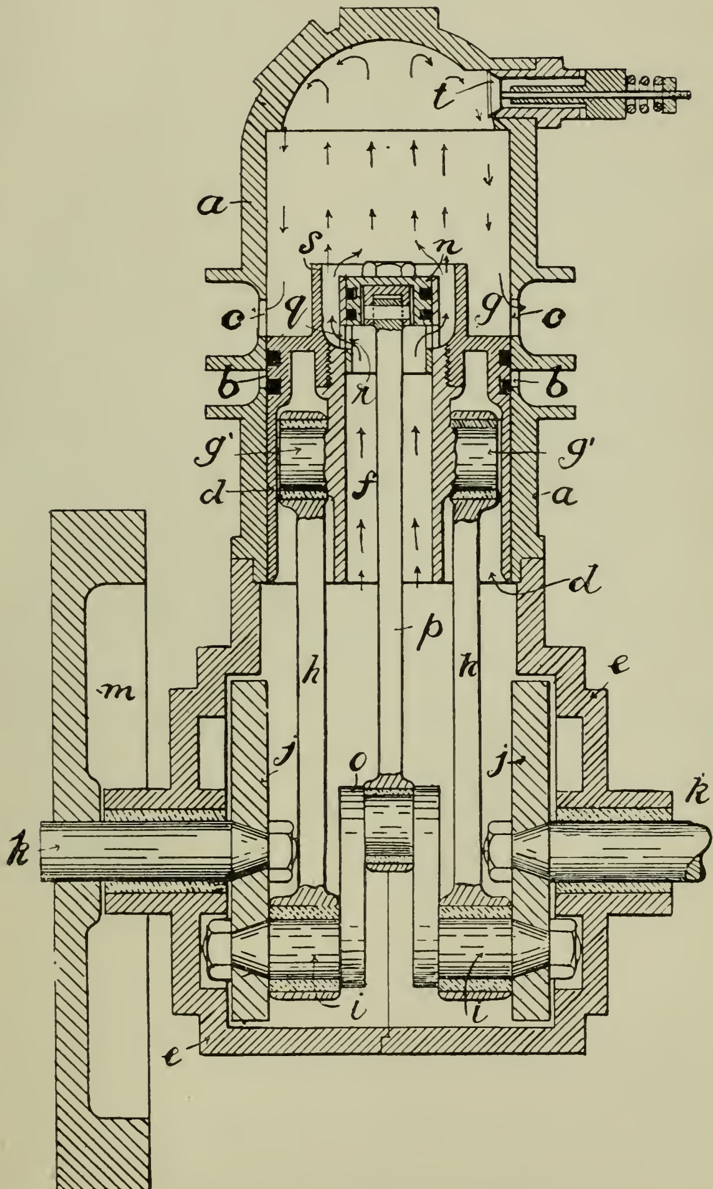
Hallett and Blackmore's Engine.

This invention consists essentially in the employment of duplex pistons, one working in a cylinder formed in the main piston, whilst the latter operates in the ordinary or active cylinder, the central piston and cylinder acting as a valve for controlling the admission of air or explosive mixture to the main cylinder for the admission of fuel and air or gas.

The illustration is a vertical section of an engine constructed in accordance with this invention, and in the method of working *a* indicates a cylinder of any suitable size provided with a ring or series of air or gas inlet ports *b*, and *c* a further ring of exhaust

ports, both arranged in suitable positions in the length of the cylinder with relation to the operation of the main or working piston *d*. *e* is a crank case on which the cylinder is mounted, and which is adapted entirely to enclose the cranks and connecting rods for operating the pistons and to hold a charge of gas or air in a compressed state. The main piston *d* receives and supports concentrically with its periphery a cylinder *f*. This cylinder *f* is provided with trunnions *g′* on which the small ends of two connecting rods *h* are mounted, the large ends of such rods being coupled to crank pins *i* formed on or secured to crank discs or cranks *j* mounted on the main shaft *k* of the engine, which also carries a fly-wheel *m*, the discs and rods being within the crank casing as already stated. The piston *n* working within the cylinder *f* is coupled to a crank *o* forming an extension from the crank pins *i* by a connecting rod *p*. At the upper end of the cylinder will be found a ring or series of ports *r*, whilst the main piston *d* is provided with a tubular extension or deflecting wall *s* of sufficient size to leave an annular passage between it and the upper end of the cylinder *d*, this passage being of such construction as will impart the highest velocity to the incoming gas or air, causing such to pass up the centre of the main cylinder to the head of the latter, thence to be deflected outwardly and downwardly to the sides of the cylinder as indicated by the arrows. By this action the exhaust gases are cleared entirely out of the latter through the ports *c*, thereby leaving the full capacity of the cylinder for the fresh charge.

In the illustration the main piston is shown at the lowest point of its stroke, with exhaust ports *c* completely open and inlet ports *b* completely closed, whilst the central piston *n* has about completed its upward stroke, the exact position of the piston being determined by the amount of lead and stroke given to the crank *o*. The ports *q* are also entirely open. Assuming, however, that the main piston is at the extreme point of its upward stroke, the small piston end would be about to commence its upward stroke, the inlet ports in the main cylinder being open, whilst the ports in the cylinder *f* would be closed. There would thus be communication for gas or air through the ports *b* with the interior of the crank case *e*, so that on the descent of main piston the gas in the crank case would be compressed. Immediately the main piston reached the bottom of its stroke the ports *q* would be opening, thus allowing the compressed gas or air to rush through the ports into the upper portion of the cylinder *a*, the exhaust ports *c*, which are likewise open, having been so opened to allow the exhaust gas on the former stroke to escape. As the gas from the crank case passes through the ports *q* the deflector *s* directs it to the upper end of the dome-shaped cylinder, by which it is deflected downwards towards the walls of the cylinder to assist in expelling the remaining products of combustion and so



HALLETT AND BLACKMORE'S ENGINE.

completely scavenging the cylinder. As the main piston rises the exhaust ports *c* are closed by it and the ports *q* by the central piston so as to allow the gas to be compressed in the cylinder in condition for firing. The firing takes place, and the main piston is given its downward stroke, again compressing the charge of gas or air which has been drawn into the crank case as a result of the inductive action of the main piston creating a partial vacuum in the crank case, which allows the explosive mixture or air to enter the latter freely.

An engine on this principle $2\frac{3}{4}$in. bore by 2in. stroke gave very good results. A Longuemare carburettor was attached to the crank-case inlet ports, and revolutions from 300 up to 2,000 per minute were obtained with a rough brake test, and by calculation the power given was about 1 B.H.P. at 1,200 r.p.m.

It would appear from the drawing shown that this engine suffers from one or two disadvantages, the first one being that communication is not made between the outside atmosphere or carburettor and the inside of the crank case except at such times as the lower end of the piston *d* uncovers the port *b*. Such an arrangement results in spasmodic gulps of mixture being taken under considerable pressure differences, but it would be a fairly simple matter to get over this by taking advantage of the three-port American system.

However, it would be necessary to fit a lower ring to the piston to retain the charge in the base chamber during the descent of the piston, otherwise the charge would creep up through the inlet ports. The presence of the cylindrical extension or deflector *s* might cause a good deal of trouble in working, through becoming hot, and one would anticipate this portion burning away. However, the continual rush of incoming charge might act favourably in keeping the temperature down.

It is to be feared that the extra expense involved in constructing an engine of this type would scarcely be justified in the way of results obtained as compared with other types of engines using crank-chamber compression.

4th December, 1911.

JOHN KENNEDY, VICE-PRESIDENT,

IN THE CHAIR.

THE DESIGN OF TALL CHIMNEYS.

By HENRY ADAMS, M.Inst.C.E., M.I.Mech.E., F.S.I., M.S.A. &c.

INTRODUCTORY.—Architects in the course of their practice, have frequently to furnish designs for special constructions, and although they sometimes adopt the sensible course of calling to their aid the services of an expert, they more frequently draw out what they think ought to do, and place the responsibility upon the contractor. The present condition of general knowledge upon the subject of the stability of tall chimneys is strikingly shown in connection with the Mechernich shaft.* This was designed to withstand a wind pressure of 160lb. per sq. ft., Prof. Rankine calculated that it would stand only 70lb. per sq. ft., while Mr. R. J. Hutton, a later writer, estimated that a wind pressure of only 32lb. per sq. ft. over the whole height would be sufficient to damage it. Tall chimneys ought to be designed upon scientific principles, so that there is an absolute guarantee for their stability, and in the following paper the author desires to elucidate these principles.

HEIGHT.—In designing a tall chimney† it is desirable first to know what height to make it. Forty-five feet is an ordinary height to serve two steam boilers, but in some towns, as Manchester and Leeds, 90ft. is the minimum allowed. They are sometimes proportioned for height according to the coal burnt per week of 56 hours, thus —

4	tons	per week	=	75	feet high.
13	,,	,,	=	100	,,
26	,,	,,	=	120	,,
50	,,	,,	=	150	,,
100	,,	,,	=	180	,,
150	,,	,,	=	200	,,

This table is checked by the graphic curve shown in Fig. 1. Another rule is to make the height of the chimney three times length of boiler + twice distance of furthest boiler to chimney. This allows 1ft. of height for every foot the gases travel round the boiler and 2ft. of height for every foot of external flue. And again, a round chimney should not exceed 25 times its internal

* Trans. Soc. Eng., 1887. Paper by R. J. Hutton on "The Stability of Chimney Shafts."

† In different districts this would be known as a high chimney, mill chimney, chimney shaft, chimney stack, chimney stalk, smoke stack, furnace shaft, boiler shaft, etc.

Height of Chimney
According to consumption of coal

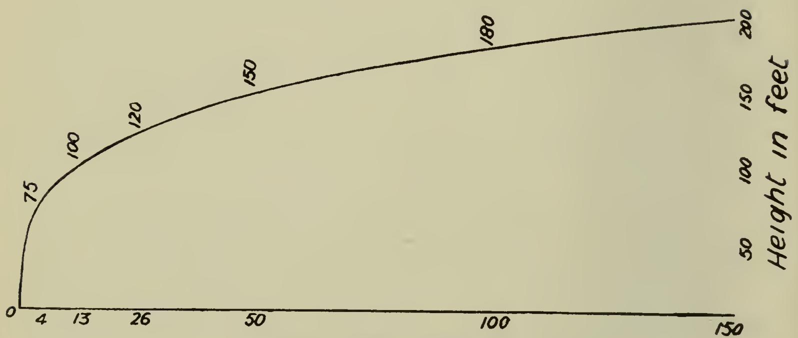


FIG. 1

diameter in height. In many modern power stations Babcock & Wilcox boilers, and Green's economisers, are used ; what is saved in obstruction in the boilers is lost in the economisers, so that no material difference arises, but the chimney shafts are as a rule only from 75 to 100ft. high and of very large sectional area. For chemical works, or where poisonous fumes are emitted, they should be higher than for ordinary steam boilers, in order to disperse the fumes at such a height that they may be diluted to a harmless condition by the time they reach the ground. The Townsend chemical works chimney at Glasgow is 454ft. high and was, when built, the highest in the world.

Sectional Area.—The sectional area or internal diameter is the next point to decide, and there are many different rules, some depending only upon the coal consumption, others upon the fire-grate area, and others upon the water evaporated in a given time. Simple approximate rules are :—

(*a*) 1 sq. ft. area for each cwt. of coal burnt per hour.

(*b*) area = $\frac{1}{10}$ of the total fire-grate area, each flue being $\frac{1}{5}$ of its fire-grate area, and main flue $\frac{1}{8}$ of total.

(*c*) $2\frac{1}{2}$ sq. ins. per indicated horse-power of the engine.

(*d*) If the height of the chimney is taken into account, as of course it should be, then on the average—

$$\text{area} = \frac{\text{lb. of coal burnt per hour,}}{12\sqrt{\text{height in feet.}}} \text{ or } \frac{\text{fire-grate area sq. ft.}}{1 \cdot 5\sqrt{\text{height in feet.}}}$$

Shape.—The necessary sectional area being obtained, it should next be decided whether the chimney is to be round, octagonal, or square. It is generally acknowledged that circular chimneys have the best appearance, at least above the pedestal, which is usually square, and from which the circular part springs

by broached angles. Octagonal chimneys have the next best effect, some even consider that they are more sightly than round chimneys, while square chimneys always look more or less heavy and are only suitable for short stacks of large area, such as are generally used in modern central station work. The circular chimney is most efficient for its area, as it takes the least material and there are no angles in which soot may cling, but with any chimney it is desirable to add 2ins. all round to the calculated minimum area to allow for friction. Octagonal chimneys require special bricks for the angles in alternate courses, to produce the best work.

WIND PRESSURE.—The comparative efficiency according to the shape of cross section may also be considered from the point of view of obstruction to the wind, that which offers the greatest obstruction requiring the greatest stability or quantity of material apart from other considerations. It is not yet definitely settled what is the pressure of the wind upon a plane surface due to a given velocity, and still less is known of the effect upon a surface inclined to its direction. We shall generally be quite safe, however, if we allow for ordinary purposes a pressure of 56 lb. or $\frac{1}{2}$cwt. per sq. ft. on a plane surface normal to the direction of the wind, and even half of this may be sufficient in many cases. When we come to fix the value of these figures against an inclined or curved surface we find much difference of opinion and no sufficient experimental evidence.

A formula agreeing closely with Hutton's experiments* is—

$$P = a\,p\,(\sin\theta)^{1.84 \cos\theta}$$

where P = total pressure in lb.

a = area of surface in sq. ft.

p = normal pressure lb. per sq. ft.

θ = angle of incidence.

and this is the basis of the majority of tables of effective pressures; but Hutton experimented on a surface of only 22 sq. ins. area, which was too small to be of much practical value.

Some years ago† the author suggested a variable allowance according to the width and height of the structure, which would cover all cases and be more in accordance with modern experiments. His empirical formula for this purpose is now—

$$\log p = 1\cdot125 + 0\cdot32 \log h - 0\cdot12 \log w$$

where p = ultimate wind pressure in lb. per sq. ft. necessary to be allowed for against a plane surface normal to the wind.

h = height in feet of centre of gravity of surface considered, above ground level.

w = width in feet of part to be taken as one surface.

* See paper by the author on "Wind Pressure on Roofs," read before the Society of Architects, 14th March, 1893.

† See discussion on a paper by R. J. Hutton on "The Stability of Chimney Shafts," Trans. Soc. Eng., 1887.

and when the surface is inclined at θ degrees to the direction of the wind, the ultimate pressure normal to the surface may be taken as $= p \sin \theta$, or its effect in the same direction as the wind $= p \sin^2 \theta$ (see Fig. 2).

Effect of wind on inclined surface

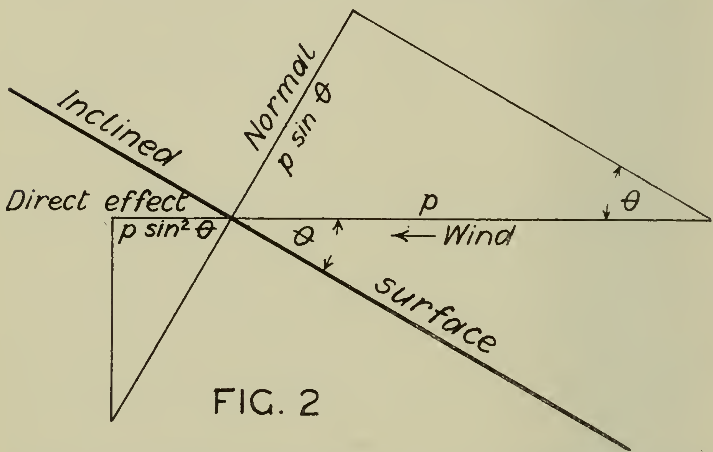


FIG. 2

This would give allowances as in the following table for which the curves are plotted in Figs. 3 and 4.

WIND PRESSURE LB. PER SQ. FT. ON PLANE SURFACE.
(For very exposed positions 25 per cent. may be added.)

HEIGHT IN FEET.	WIDTH IN FEET.						
	5	10	20	50	100	200	500
150	54·6	50·3	46·3	41·4	38·1	35·1	31·4
100	48·0	44·2	40·7	36·4	33·5	30·8	27·6
50	38·4	35·4	32·5	29·1	26·8	24·7	22·1
20	28·7	26·4	24·3	21·7	20·0	18·4	16·5
10	23·0	21·1	19·5	17·4	16·0	14·8	13·2
5	18·4	17·0	15·6	13·9	12·8	11·8	10·6

MULTIPLIERS FOR ANGLE.

	10	20	30	40	50	60	70	80	90
Sin θ	·174	·342	·500	·643	·766	·866	·940	·985	1
$\text{Sin}^2\theta$	·0303	·117	·250	·413	·587	·750	·884	·970	1

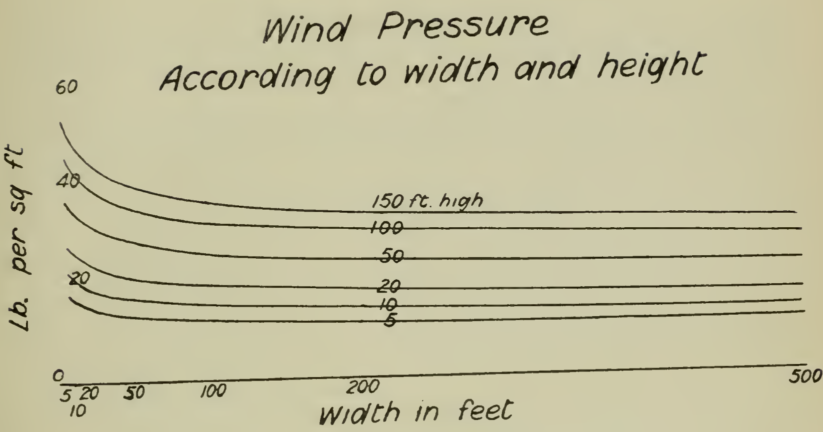


FIG. 3

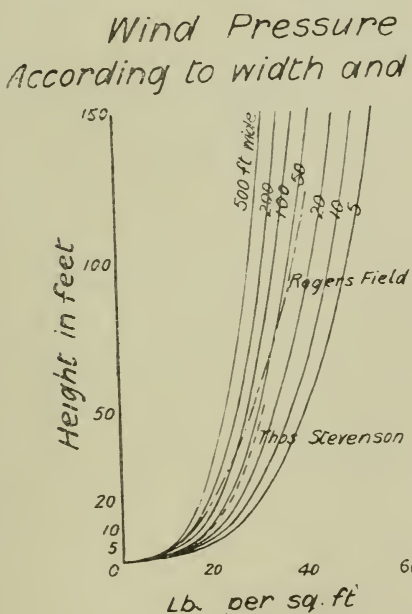


FIG. 4

In the case of a boundary wall the length to consider would be a portion equal to say $1\frac{1}{2}$ times the height, or the width between the buttresses. In the case of a roof the distance from centre to centre of the trusses should be taken, unless the stability

of the whole structure be under consideration, when the full length should be taken. In the case of a lattice girder bridge 50 per cent. should be added to the actual area offered to the wind and both girders taken.

The lower part of the above table, shown graphically in Fig. 5, gives the multipliers for angle when the surface is not at right

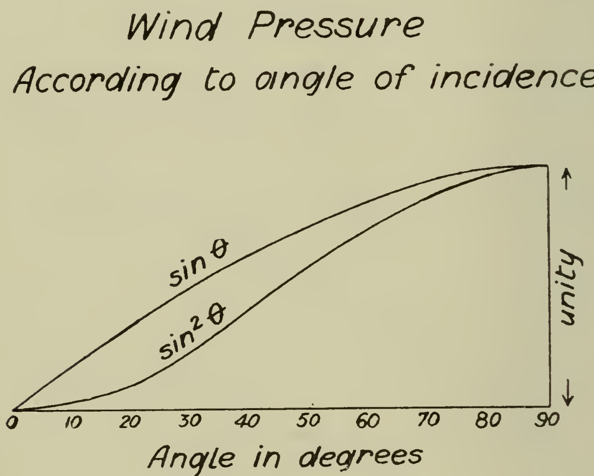


FIG. 5

angles to the direction of the wind, the sines being used for obtaining the normal pressure on an inclined surface such as a roof, and the $\sin^2$ for the effective pressure in the same direction as the wind, on such a surface as a square chimney placed diagonally.

Theoretically, account should be taken of the effect of the batter in determining the wind pressure on a chimney, but this is so slight that it may usually be omitted.

Pressure on Square Chimney.—A square chimney will give the same resistance whether facing the wind or standing diagonally to its direction, the greater area of the inclined surface and the reduced pressure upon it making the same total as the flat side under the full pressure.

Pressure on Circular Chimney.—With circular chimneys a very serious difference of opinion exists as to the effective pressure of the wind, as shown by the following list of multipliers recommended :—

Rankine ..	= ·5	Prof. Hutton	= ·66
Wilson	= ·56	Gaudard ..	= ·66
Borda	= ·57	Bressé ..	= ·78
Sir B. Baker ..	= ·57	Adams ..	= ·7854

Molesworth's Pocket Book says somewhere (but owing to the very imperfect index the author has been unable to find the statement again) that "the pressure of the wind upon a cylindrical surface has been given at $\frac{1}{2}$ to $\frac{2}{3}$ of that against a normal plane, while experiments show it to be nearer $\frac{3}{4}$." C. B. Bender in a paper on "Wind Pressure," read before the Inst.C.E. in 1882 says "cylinders have the special co-efficient of 0·54, but larger surfaces probably increase this value." The author's investigations lead him to adopt $\frac{\pi}{4}$ as the multiplier, which if incorrect is at any rate on the safe side. The area taken for wind pressure in the case of a circular chimney is the diametral vertical plane and no further allowance need be made for suction on the lee side.

PRESSURE ON OCTAGONAL CHIMNEY.—An octagonal chimney has two extreme positions with regard to the wind, viz., when it is acting directly against one face, and when acting directly against one edge. For the former case the author's multiplier would be 0·83 and for the latter 0·82; there is not much difference, but the latter co-efficient gives rather the higher result as it is taken against the width over angles.

PRUSSIAN GOVERNMENT RULES.—In April 1902, the Prussian Government issued regulations for the construction of chimney stacks. Square stacks to be designed for a wind pressure of $25\frac{1}{2}$ lb. per sq. ft. with the centre of pressure at the centre of gravity of diametral vertical plane. Octagonal stacks, 71 per cent. of the above pressure and circular stacks, 67 per cent. (*Engineering Record*).

THICKNESS OF BRICKWORK.—Up to 150ft. high or 5ft. inside diameter the top length is generally one brick (9in.) thick; above that height or diameter, the top length should be $1\frac{1}{2}$ bricks thick and the thickness should be increased by a $4\frac{1}{2}$in. set-off at every 20ft. below the top. The outlet at top, and the throat or internal diameter at each set-off, should be of the calculated size to give the necessary area plus allowance for friction. Sometimes one hears it recommended that the top of the chimney should be contracted, to cause the expulsion of the gases at a greater velocity and so to prevent down draught. It is said also that as the gases cool in their passage up the chimney they require a smaller sectional area to keep the velocity uniform. In general no attention is paid to either of these theories and the section is kept as uniform as the other requirements will permit.

BATTER.—If the diameter of the throat is kept uniform and a $4\frac{1}{2}$in. set-off occurs at every 20ft., the intermediate portions being of uniform thickness, a batter of 1 in 53·33 will be given, but the London County Council insist on a minimum batter of 1 in 48 = $2\frac{1}{2}$in. in 10ft., and besides that it will be requisite in

most cases to provide a fire-brick lining for at least the bottom 15 or 20ft., having a thickness of 4½in. and a clear space from the outer brickwork of 1½ to 2in., necessitating a still greater batter.

Chimney Cap.—The chimney cap or cornice, by the London County Council rules, must not project more than the thickness of the brickwork upon which it rests. It may be of cast-iron casings bolted together and filled with brickwork ; or of granite or other good weathering stone, the separate blocks being cramped together with galvanised iron cramps, or with an iron hoop sunk into the top and protected with cement ; or of brick-work in cement.

Diameter at Base.—There is also an important rule of the London County Council, which says " the width of a shaft at the base, if square on plan must be at least one-tenth, and if circular on plan at least one-twelfth of the total height."

Fire-brick Lining.—The fire-brick lining must be entirely self-supporting and have a clear space behind, to allow for expansion and contraction independently of the main structure, which would be prevented if dirt and dust were to get behind it. It is therefore necessary to cover the top of the space by an over-sailing course of bricks built out from the inside of the main shaft, protecting the space, but allowing a clearance above the lining of ⅛in. for every 5ft. of its height, to permit of its expansion when heated. The average height of this lining is $\frac{1}{5}$ height of shaft + 10ft. A common height is 20ft. and thickness 4½in. ; when of greater height it is necessary to make the lower part 9in. thick. No air bricks should be inserted in the outer wall, as is sometimes done with the idea of cooling the air space, any such openings being very detrimental to the draught. The only possible inlet for air to the chimney shaft should be through the fire bars or over the surface of the incandescent fuel.

The smoke inspectors of the L.C.C. have lately recommended openings into the chimney shafts near the bottom to reduce the smoke nuisance. The real effect is to dilute the smoke with air before it reaches the chimney top so that it is not so black when expelled, but it does not reduce the actual amount of carbon emitted except so far as it tends to spoil the draught and so to reduce the fuel consumption and boiler efficiency.

Stability.—Having drawn out the vertical section to suit the conditions it will be essential to test the stability by calculation, but this is a somewhat complex matter and requires some preliminary data that will now be dealt with.

Materials and Weight.—The weight of each portion of the shaft, *i.e.*, between each set-off, should be obtained separately so that the figures can be used singly or together. The weight will

depend very much upon the material. Many chimney shafts are built of ordinary stock bricks and ground stone-lime mortar, and may be taken at 112 lb. per cub. ft. Others are built of solid machine pressed bricks and lias lime mortar, and may be taken at 126 lb. per cub. ft. Some builders prefer perforated radial bricks and Portland cement mortar, weighing say about 120lb. per cub. ft. Others consider that cement is too unyielding and that a shaft has greater ultimate stability if it sways slightly in a gale, which they fear the use of cement mortar might prevent. The bond usually adopted is one course of headers to four courses of stretchers, but sometimes tall chimneys are built in English bond, and occasionally in all headers.

The 450ft. chimney at St. Rollox, Glasgow, is built in old English bond. The 300ft. chimney at Johnson's Cement Works, Greenhithe, is built in Flemish bond. At Gosling's Cement Works, Northfleet, a 220ft. chimney is built in stretching bond. At Barker's brick works, Worcester, the 160ft. chimney is built with three stretchers to one header. At the Surrey Commercial Docks the 110ft. chimney is constructed with all headers on the circular face. For the 100ft. chimney at Farringdon Street Goods Station, Beart's patent perforated radiating bricks were used in the circular shaft, laid all headers on external face.

Hoop iron galvanised, or painted with cement wash, may be inserted at intervals of 5ft. in height. The work should not be carried up too quickly, 3ft. per day being quite sufficient unless the work is in cement.

The solid contents C of any portion of a circular shaft, having bottom outside diameter in ft. D, top outside diameter d, uniform thickness t, and height h will be $C = \pi h t\left(\frac{D + d + \sqrt{Dd}}{3} - t\right)$ and the weight will be C × wt. of 1 cub. ft. of the material.

Safe load on Material.—Assuming best workmanship and material the maximum safe load may be taken as follows, being about 50 per cent. higher than would be allowed for live loads or inferior conditions.

	Tons per sq. ft. Compression.
Granite	25
Portland and compact limestone	20
Hard York stone	15
Blue brick in cement	12
Stock ,, ,, ...	10
,, ,, lias mortar	8
,, ,, grey lime mortar	6
Cement concrete 6 to 1	9
Deep clay (foundations not less than 10ft. from surface), gravel and compact earth ..	3
Made ground rammed in layers	$1\frac{1}{2}$

SAFE LOAD ON MATERIAL (*continued*).	Tons per sq. ft. Tension.
Grey lime mortar (1 to 2)	1·0
Lias lime mortar (1 to 2)	1·5
Portland cement mortar (1 to 3)	2·0

FOUNDATION.—It is important to note that a tall chimney should stand on an independent foundation in order that the settlement, or compression of the soil, may be uniform. When a chimney is built close alongside a boiler house, or within the four walls of a warehouse, it is sometimes placed on an extension of the other foundations and bonded in with other work, but this invariably leads to unequal settlement and subsequent cracks in the brickwork. It is evident that an ideal site would be on virgin soil of uniform character, preferably firm gravel, and not over old excavations, or a filled-in watercourse, or over old shaft workings, although all these positions have been adopted from carelessness or necessity.

PRINCIPLES OF STABILITY.—The principles of stability can best be illustrated by taking a solid square brick pier say 3ft. square and 30ft. high, weighing 1 cwt. per cub. ft. The total weight will be $3 \times 3 \times 30 \times 1 = 270$ cwt., the area of base $3 \times 3 = 9$ sq. ft., the mean pressure on base $\frac{270}{9} = 30$ cwts. per sq. ft. The resultant of the weight of all the parts passes vertically through the centre of gravity of the mass and cuts the centre of the base. If the wind be assumed to blow horizontally against one side the effect will be collected at the centre of the face and act with a leverage of half the height as shown in Fig. 6, and the resultant of the two forces P and W will gradually approach the outer edge of the base as the wind pressure increases. Assuming that the pier could overturn on the outer edge as a fulcrum,

Resultant of Thrust

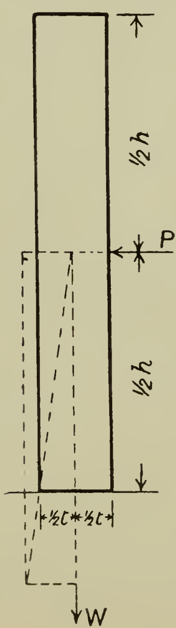


FIG. 6

without crushing, we have a case of simple leverage, $W \times \frac{1}{2}t = P \times \frac{1}{2}h$, or $P = W\frac{t}{h} = 270 \times \frac{3}{30} = 27$ cwt., and as P is made up of $3 \times 30 \times p$, we have $p = \frac{27}{3 \times 30} = 0 \cdot 3$ cwt. or $33 \cdot 6$ lb. per sq. ft. Graphically the resultant will pass through the extremity of the base as shown by dotted lines. Now this is simple, but it is not true; the brickwork on the extreme edge would crush, and the pier would therefore overturn with a somewhat lower pressure. In practice we do not want our structures to overturn and in order that they shall be safe when first built we cannot allow any tensile stress on the inner edge. We therefore want to find what position the resultant must occupy for the pressure on inner edge to be reduced to zero. It will be observed that the wind being a horizontal force cannot add anything to the vertical force due to the weight of the structure, but it can increase the intensity of the pressure on a part of the base by forcing the resultant over towards one side and so altering the distribution. While the resultant is in the centre of base the pressure is uniform, as shown by the ordinates in Fig. 7, and as the resultant travels over

Reaction according to position of Resultant

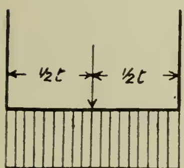


FIG. 7

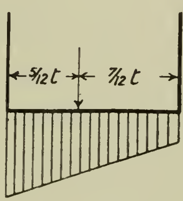


FIG. 8

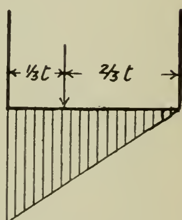


FIG. 9

Resultant of Thrust

to one side the pressure increases at one edge and diminishes at the other as in Fig. 8, until finally the ordinates form a triangle as in Fig. 9. This occurs in a rectangular base when the resultant falls at the extremity of the middle third and is the origin of all false notions with regard to the efficacy of the middle third. The resultant falling within the middle third means no more than that the pressure then does not fall below zero on the inner edge; there is no guarantee that it may not be exceeding the safe load on the outer edge. On the other hand there are many cases where the resultant falls beyond the middle third and

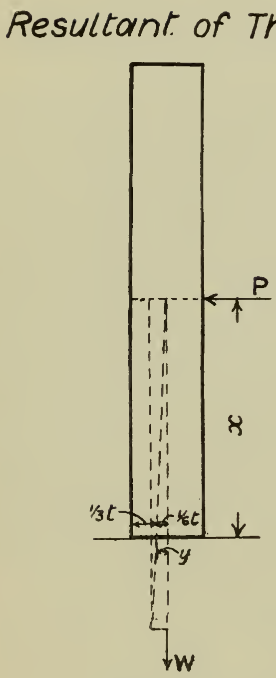


FIG. 10

the structure is still only loaded within safe limits. In each of these examples the area of the shaded part, representing the forces of reaction, will be found equal, and it follows as a necessity that the maximum pressure indicated by the triangular Fig. 9 is double that shown by the parallelogram Fig. 7. In order to find the wind pressure to limit the resultant to this position we have to consider the altered leverage of the resistance; the weight of wall acting through its centre of gravity Fig. 10 has now only a distance of $\frac{1}{6}t$ to the resultant, or centre of reaction, which is the virtual fulcrum, we therefore have the equation $W \times \frac{1}{6}t = P \times \frac{1}{2}h$ whence $P = \frac{W \times \frac{1}{6}t}{\frac{1}{2}h} = \frac{Wt}{3h} = \frac{270 \times 3}{3 \times 30} = 9$ cwt., and $p = \frac{9}{3 \times 30} = 0 \cdot 1$ cwt. $= 11 \cdot 2$ lb. per sq. ft. as the maximum wind pressure instead of $33 \cdot 6$ lb. as found for simple overturning. This will produce a maximum intensity of pressure upon the base of $30 \times 2 = 60$ cwt. $= 3$ tons per sq. ft. which is below the safe limit, but we cannot increase it without reducing the pressure below zero on the inner edge, and although this might under certain circumstances be permissible, it is not generally considered desirable in the case of tall chimneys.

It will be well to use this illustration of a solid pier a little longer while we consider another point. Referring to the last figure we can put the result another way. Making a plan of the base as in Fig. 11 we can draw a triangle inside as shown by the ordinates or shading lines, and if the base of the triangle represent the maximum pressure then the ordinates show how the pressure reduces towards the inner edge. But we may look at it from another point of view, by assuming all the energy of resistance to be taken up by the particles within the triangle so that they are all exerting the same pressure, while those

outside the triangle are exerting none. This would give the same result and it explains better what is meant by resistance area. The centre of gravity of the shaded triangle is the centre of effort of the resistance.

Tall Chimneys
Resistance areas of different sections

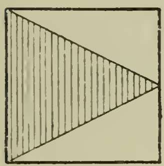


FIG. 11

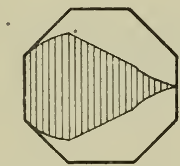


FIG. 13

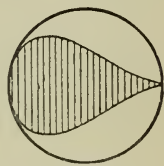


FIG. 15

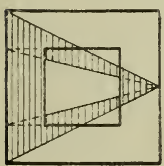


FIG. 12

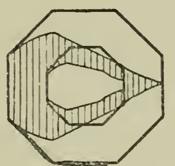


FIG. 14

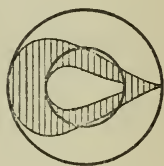


FIG. 16

Application to Chimney Shafts.—The reason so much time has been spent over the plain brick pier is that we shall be able to deal with complex chimney shafts the more readily. Nearly all the different forms of bed joint can be reduced to a few simple diagrams. These are collected together in Figs. 11 to 16, the shaded part being the resistance area, or measure of effective resistance, of each. Another form of section may occasionally be found, viz., square with two buttresses on each face, the resistance area of which would be found in a similar manner to the preceding, and the centre of gravity would be found experimentally by cutting out the area in drawing paper and suspending it from two points. These shaded portions have been described as resistance areas, although they correspond exactly with the inertia areas for a neutral axis coinciding with one edge. The reason is that in calculation, account is taken of the actual conditions, viz., a uniformly distributed load, and a bending moment producing compression on one side and tension on the other side of a neutral axis passing through the centre of gravity of the section.

General formula for Stability.—The general formula for a structure subject to a direct stress and also to a bending moment is $K = m + \frac{M}{Z}$ $\quad k = m - \frac{M}{Z}$

where K = maximum intensity of pressure in tons per sq. ft.

k = minimum ,, ,, ,, ,, ,, ,,

m = mean ditto, due to direct stress, tons per sq. ft.

M = bending moment in foot-tons.

Z = modulus of section in foot units.

This applies to all cases where the stress on the inner edge is not reduced below zero, and to such other cases as permit of a tensile stress.

d = deviation of centre of pressure when pressure becomes zero at opposite edge.

A = area of bed joint.

then $d = \dfrac{Z}{\mathrm{A}}$

Also let—

W = superincumbent weight in tons.

A = area of section in sq. ft.

l = distance from resultant to edge of section in ft.

D = outside diameter or width in ft.

d = inside diameter or width in ft.

Then for solid square, Fig. 11.

$$A = D^2,\ l = \tfrac{1}{3}D,\ Z = \tfrac{1}{6}D^3$$

for hollow square, Fig. 12.—

$$A = D^2 - d^2,\ l = \frac{2D^2 - d^2}{6D},\quad Z = \frac{D^4 - d^4}{6D}$$

for solid octagonal, Fig. 13.—

$$A = (2\sqrt{2} - 2)D^2,\quad l = \tfrac{3}{8}D,\quad Z = \frac{\sqrt{2} - 1}{4}D^3$$

for hollow octagonal, Fig. 14.—

$$A = (2\sqrt{2} - 2)\ (D^2 - d^2,\ l = \tfrac{3}{8} \times \frac{D^2 - d^2}{D},\ Z = \frac{\sqrt{2} - 1}{4} \times \frac{D^4 - d^4}{D}$$

for solid circular, Fig. 15.

$$A = \frac{\pi}{4}D^2,\quad l = \tfrac{3}{8}D,\quad Z = \frac{\pi}{32}D^3$$

for hollow circular, Fig. 16.—

$$A = \frac{\pi}{4}(D^2 - d^2),\ l = \tfrac{3}{8}\frac{D^2 - d^2}{D},\ Z = \frac{\pi}{32}\frac{D^4 - d^4}{D}$$

and if A be made use of to find Z,

Z = for solid square	.. ..	$A \times \frac{1}{6}D$
,, hollow ,,	.. ..	$A \times \frac{1}{6}\dfrac{D^2 + d^2}{D}$
,, solid octagonal	..	$A \times \frac{1}{8}D$
,, hollow ,,	..	$A \times \frac{1}{8}\dfrac{D^2 + d^2}{D}$
,, solid circular	..	$A \times \frac{1}{8}D$
,, hollow ,,	..	$A \times \frac{1}{8}\dfrac{D^2 + d^2}{D}$

It will be found that—

	Square.	Octagonal.	Circular.
$l =$ for solid section	$\frac{1}{3}D$	$\frac{3}{8}D$	$\frac{3}{8}D$
,, average hollow ..	$\frac{1}{4}D$	$\frac{1}{3}D$	$\frac{1}{3}D$
,, infinitely thin	$\frac{1}{6}D$	$\frac{1}{4}D$	$\frac{1}{4}D$

and many designers are satisfied with these approximations, but for important work the exact distance should be obtained graphically or by exact calculation.

ASCERTAINING STABILITY.—Now the stability can be worked out from these diagrams and formulæ in two ways. Taking the 3ft. brick pier as an example of a solid square bed joint $Px = Wy$, but $y = \frac{1}{2}D - l = \frac{1}{2}D - \frac{1}{3}D = \frac{1}{6}D$, and $x = \frac{1}{2}h$, $\therefore P = W \times \frac{\frac{1}{6}D}{h} = \frac{W}{3} \times \frac{D}{h}$, etc. as already worked out, when p was found $= 11 \cdot 2$lb. per sq. ft. and $K = 3$ tons per sq. ft. And by the second method $m = \frac{W}{A} = \frac{270}{9} = 30$ cwt. $= 1 \cdot 5$ tons, $M = p \times h \times D \times \frac{1}{2}h \times coeff.$ $= 11 \cdot 2 \times 30 \times 3 \times 15 \times 1 = 15{,}120$ ft.-lb. $= 6 \cdot 75$ ft.-tons. $Z = \frac{1}{6}D^3 = \frac{3^3}{6} = \frac{27}{6} = 4 \cdot 5$ft. units

$$K = m + \frac{M}{Z} = 1 \cdot 5 + \frac{6 \cdot 75}{4 \cdot 5} = 3 \text{ tons per sq. ft. as before.}$$

In practice it will generally be necessary to work the other way round, and to make allowance for the taper of the portion under consideration, the stability of a chimney being usually measured by the maximum safe wind pressure. We know the maximum pressure on the bed joint will be twice the mean pressure, $K = \frac{W}{A} \times 2$, then the area must be such that K does not overstep the limits previously laid down by the table of safe loads on materials.

CENTRE OF WIND PRESSURE.—Let h = height from bed joint to centre of gravity of diametral plane, which will be the centre of wind pressure, H = whole height of portion, D = lower diameter and d = upper diameter, then—

$$h = H \times \frac{D + 2d}{3(D + d)}, \text{ and } p = \frac{W(\frac{1}{2}D - l)}{hH\frac{1}{2}(D + d)}$$

For rapid proof we may apply this to the square pier,

$$\text{thus, } p = \frac{270\ (\frac{1}{2} \times 3 - 1)}{15 \times 3 \times 30} = 0 \cdot 1\text{cwt.} = 11 \cdot 2 \text{ lb. as before.}$$

WHEN TENSION IS PERMISSIBLE.—When tension is permissible on the inner edge the wind pressure may be increased, so that the resultant is forced nearer to the overturning edge. The maximum pressure will under these circumstances be $K = \frac{W}{A}\ (4 - 6\frac{l}{D})$

and the minimum, or tension, $k = \frac{W}{A}\left(6\frac{l}{D} - 2\right)$.

Air and Combustion.—There are now some interesting points to note with regard to the use of the chimney. With air at 60° Fahr. 30in. bar. about 13 cub. ft. weigh 1 lb., and 12 lb. of air (156 cub. ft.) are required to combine with the constituents of 1 lb. of coal for perfect combustion, but to allow for working conditions it is necessary to provide 24 lb. (312 cub. ft.), which is equal to 700,000 cub. ft. of air per ton of coal. Putting it in another way the air and smoke together at a temperature of say 300° F. equal about 2,000 cub. ft. per cubic foot of water evaporated. The maximum economical draught for boilers is that arising from, or equivalent to, the pressure due to ½in. head of water, causing a consumption of about 36 lb. coal per hour per sq. ft. of fire-grate area. The temperature of combustion in the furnace is about 2,400°F. The temperature of the gases is generally ascertained by hanging strips of metal foil in the flues on an iron wire, and noting which are melted by the heat, viz., copper 2,000°, aluminium 1,800°, zinc 750°, lead 630°, tin 440°. A 3in. cast iron pipe is sometimes built in the base of the chimney for the purpose of introducing these test pieces or a pyrometer, or for testing the suction. The temperature may be as low as 300° F. with any Cornish or Lancashire boilers or as high as 1,000° F. with water-tube boilers. At 600° F., which is about the usual temperature of the escaping gases, the volume of air entering the furnace is doubled on exit.

Chimney Draught.—The force of the draught in a chimney stack is the deficiency of weight of the column of rarefied air in the chimney compared with a similiar column of the external air. The velocity in ft. per sec. is roughly 2½ times the square root of the height in feet. As regards smoke prevention there are several patents on the market but a good stoker is the best smoke preventer.

Horse-power of Chimney.—The horse-power of a chimney is sometimes spoken of. For a round chimney the following rules have been given :—

(1) H.P. $= 3\frac{1}{3}$ (area sq. ft. $- 0\cdot6\sqrt{\text{area}}) \times \sqrt{\text{height ft.}}$

(2) H.P. $= 2\frac{1}{2} \times$ diam. ft.$^2 \times \sqrt{\text{height ft.}}$

(3) H.P. $= \dfrac{\text{diam. ins.}^2 \times \sqrt{\text{height ft.}}}{70}$

(4) H.P. $= \dfrac{\text{diam. ins.}^3}{300}$

but one would have supposed there were enough variations of horse-power without introducing another.

APPENDIX.

Design for Chimney.—In order to emphasize the author's description he now proposes to design a tall circular chimney for 4 Lancashire boilers, each having 2 furnaces 2ft. 9in. wide × 6ft. long, burning 12 lb. coal per sq. ft. of fire grate per hour and evaporating $9\frac{1}{2}$ lb. water per lb. of coal. The boilers themselves are 7ft. 6in. diameter × 30ft. long, with Galloway tubes, and supply steam to an engine of 750 I.H.P.

Total fire-grate area $= 4 \times 2 \times 2 \cdot 75 \times 6 = 132$ sq. ft.
Consumption of coal per hour $132 \times 12 = 1584$ lb.

Consumption per week of 56 hours $\frac{1584 \times 56}{2240} = 39 \cdot 6$ say 40 tons.

Water evaporated per hour $= 1584 \times 9 \cdot 5 = 15048$ lb. $= 1504 \cdot 8$ galls.

Water used per I.H.P. per hour $= \frac{15048}{750} = 20 \cdot 064$ say 20 lb. which fairly represents modern practice with compound condensing engines.

Area of main flue $\frac{132}{8} = 16 \cdot 5$ sq. ft. say 3ft. wide × 5ft. 6in. high, invert say 4ft. below ground level.

Height of Chimney—

(*a*) from coal consumption, scaling from diagram, 40 tons per week = 140ft. high.

(*b*) from length of flues, chimney being 28ft. from further boiler. Three times length of boiler + twice length of main flue $= 3 \times 30 + 2 \times 28 = 146$, but there is something inviting about round numbers so that 140ft. may be decided upon as the height above ground level or 150ft. in all.

Sectional area of chimney,—

(*a*) from coal consumption $= \frac{1584}{112} = 14 \cdot 14$ sq. ft.

(*b*) from fire-grate area $= \frac{132}{10} = 13 \cdot 2$ sq. ft.

(*c*) from indicated horse-power (I.H.P.) of engine $= \frac{750 \times 2\frac{1}{2}}{144}$ $= 13 \cdot 02$ sq. ft.

(*d*) from coal consumption and height $= \frac{1584}{12 \sqrt{150}} = 10 \cdot 8$ sq. ft.

(*e*) from fire-grate area and height $= \frac{132}{1 \cdot 5 \sqrt{150}} = 7 \cdot 18$ sq. ft.

An allowance of 14 sq. ft. should therefore be ample without any further allowance for friction. Reference to a table of

areas shows that 4ft. 3in. diameter $=14 \cdot 18$ sq. ft. area, which may be decided upon as suitable.

Height of fire-brick lining, $\frac{150}{5}+10=40$ft.

Sketch Section.—*Data.*—Main flue 5ft. 6in. $\times$ 3ft., invert 4ft. below ground level. Chimney 140ft. high, 4ft. 3in. least internal diameter. Lining 40ft. high, 20ft. of 9in. thick and 20ft. of $4\frac{1}{2}$in., vertical. Batter not less than $2\frac{1}{2}$in. in 10ft. Least permissible outside diameter at ground line $\frac{140}{12}=11$ft. 8in. Thickness of shaft say 20ft. of 1 brick, 20ft. of $1\frac{1}{2}$ b., 20ft. of 2 b., 20ft. of $2\frac{1}{2}$ b., 20ft. of 3 b., 20ft. of $3\frac{1}{2}$ b., 20ft. of 4 b., remainder $4\frac{1}{2}$ b. Projection of cap 9in.

The diameter at ground line requires to be $2/3' \ 4\frac{1}{2}'' + 2/1\frac{1}{2}' + 2/9'' + 4' \ 3'' = 12' \ 9''$. The diameter at top requires to be $2/9'' + 4' \ 3'' = 5' \ 9''$, which fortunately gives the round number of 7ft. for taper, or $3' \ 6''$ batter on each side $=42$in. in 140ft. $=\frac{42}{14}$ins. in 10ft. $=3$in. in 10ft., or each 20ft. length increases 1ft. in diameter.

If the upper half of the fire-brick lining stands central on the lower half, the clearance at top of former will be found thus :—

$\frac{36}{10}\times 3=10 \cdot 8$in. batter, $10 \cdot 8 \times 2=21 \cdot 6$ say $1' \ 9\frac{1}{2}''$ taper, reduced outside diameter $12' \ 9'' - 1' \ 9\frac{1}{2}'' = 10' \ 11\frac{1}{2}''$. Inside diam. of shell $=10' \ 11\frac{1}{2}'' - 2/2' \ 7\frac{1}{2}'' = 5' \ 8\frac{1}{2}''$. Outside diam. lining $=4' 7\frac{1}{2}'' + 2/4\frac{1}{2}'' = 5' \ 4\frac{1}{2}''$. Clearance $=\frac{1}{2}(5' \ 8\frac{1}{2}'' - 5' \ 4\frac{1}{2}'') = 2$in. at top of fire-brick lining to be covered by oversailing course projecting say $4\frac{1}{2}$in. and with clearance above top of not less than $\frac{40}{5}\times\frac{1}{8}=$ 1in. to allow for expansion.

The clearance outside lower length of fire-brick lining at junction with upper length will be $\frac{16}{10}\times 3=$ $4 \cdot 8$in. batter, $4 \cdot 8 \times 2 = 9 \cdot 6$in. say $9\frac{1}{2}$in. taper, reduced outside diameter $12' \ 9'' - 9\frac{1}{2}'' = 11' \ 11\frac{1}{2}''$, inside diameter of shell $= 11' \ 11\frac{1}{2}'' - 2/3' \ 0'' = 5' \ 11\frac{1}{2}''$. Outside diameter of lining $=4' \ 3'' + 2/9'' = 5' 9''$. Clearance $= \frac{1}{2}(5' \ 11\frac{1}{2}'' - 5' \ 9'') = 1\frac{1}{4}$in. which will be satisfactory, but before the design is proceeded with further, the stability should be calculated.

Calculation of Stability.—The first step in calculating the stability is to determine the weight of each portion between the various set-offs. Suppose the material to be picked stock bricks laid in lias mortar, the weight may be taken at 112 lb. per cubic foot.

WEIGHT OF EACH LENGTH.—Top length $=\pi ht\left(\frac{D+d+\sqrt{Dd}}{3}-t\right)$
$\times 112 = 3\cdot1416\times 20\times 0\cdot75\left(\frac{6\cdot75+5\cdot75+\sqrt{6\cdot75\times 5\cdot75}}{3}-0\cdot75\right)$
$\times 112 = 47\cdot124\times 5\cdot493\times 112 = 28991\cdot5$ lb.

2nd length = 48371·68 lb.
3rd length = 71147·44 lb.
4th length = 97148·08 lb.
5th length = 126509·60 lb.
6th length = 159230·40 lb.
7th length = 195096·16 lb.

WEIGHT ABOVE EACH SET-OFF.—The weights will be required in totals above each set-off, they may therefore be collected as follows :—

1st set-off	.. ..		.. ..	=	28991·50
2nd ,,	28991·50	+	48371·68	=	77363·18
3rd ,,	77363·18	+	71147·44	=	148510·62
4th ,,	148510·62	+	97148·08	=	245658·70
5th ,,	245658·70	+	126509·60	=	372168·30
6th ,,	372168·30	+	159230·40	=	531398·70
7th ,,	531398·70	+	195096·16	=	726494·86

AREAS OF BED JOINTS.—The next step is to find the sectional area at the lower end of each portion, *i.e.*, the bearing surface at each set-off, viz., $A=\frac{\pi}{4}(D^2-d^2)$, d being now inside diameter.

1st set-off	$\cdot7854\ (6\cdot75^2-5\cdot25\ )$	$=12\cdot74$
2nd ,,	$\cdot7854\ (7\cdot75^2-5\cdot50^2)$	$=23\cdot82$
3rd ,,	$\cdot7854\ (8\cdot75^2-5\cdot75^2)$	$=34\cdot16$
4th ,,	$\cdot7854\ (9\cdot75^2-6\cdot00^2)$	$=46\cdot34$
5th ,,	$\cdot7854(10\cdot75^2-6\cdot25^2)$	$=60\cdot08$
6th ,,	$\cdot7854(11\cdot75^2-6\cdot50^2)$	$=75\cdot20$
7th ,,	$\cdot7854(12\cdot75^2-6\cdot75^2)$	$=91\cdot84$

MEAN PRESSURE.—The mean pressure due to the direct load will also be required at each set-off, viz. $m=\frac{W}{A}$,

1st set-off	$\frac{28991\cdot5}{12\cdot74\times 2240}$	= 1·01	tons per sq. ft.	
2nd ,,	.. .. ..	= 1·45	,,	,,
3rd ,,	.. .. ..	= 1·91	,,	,,
4th ,,	.. .. ..	= 2·34	,,	,,
5th ,,	.. .. ..	= 2·79	,,	,,
6th ,,	.. .. ..	= 3·16	,,	,,
7th ,,	.. .. ..	= 3·53	,,	,,

MODULI OF SECTION.—The modulus of section corresponding to each of these sectional areas, viz. $Z=\frac{\pi}{32}\left(\frac{D^4-d^4}{D}\right)$, d being

inside diameter, will be—

1st set-off $0 \cdot 1013 \left(\frac{6 \cdot 75^4 - 5 \cdot 25^4}{6 \cdot 75}\right)$					$= 19 \cdot 65$
2nd	,,	..	..	..	$= 35 \cdot 10$
3rd	,,	..	..	..	$= 55 \cdot 20$
4th	,,	..	..	..	$= 80 \cdot 42$
5th	,,	..	..	..	$= 111 \cdot 43$
6th	,,	..	..	..	$= 148 \cdot 91$
7th	,,	..	..	..	$= 185 \cdot 28$

Height of centre of Wind Pressure.—The height of centre of wind pressure, *i.e.* centre of gravity of diametral plane, above each set-off, viz. $h = H \times \frac{D+2d}{3(D+d)}$, d being top diameter, will be—

				ft.
Above	1st set-off		$20 \times \frac{6 \cdot 75 + 2 \times 5 \cdot 75}{3(6 \cdot 75 + 5 \cdot 75)}$	$= 9 \cdot 73$
,,	2nd	,,	$40 \times \frac{7 \cdot 75 + 2 \times 5 \cdot 75}{3\,(7 \cdot 75 + 5 \cdot 75)}$	$= 19 \cdot 00$
,,	3rd	,,	.. .. ..	$= 28 \cdot 00$
,,	4th	,,	.. .. ..	$= 36 \cdot 50$
,,	5th	,,	.. .. ..	$= 45 \cdot 40$
,,	6th	,,	.. .. ..	$= 53 \cdot 64$
,,	7th	,,	.. .. ..	$= 61 \cdot 74$

Width at centre of Pressure above each set-off.—This will be given by the formula $w = D - \frac{h}{H}(D - d)$ where h = height of c.g. of diametral plane above set-off, H = whole height above ditto, D = diameter at set-off, d = diameter at top.

1st	set-off	$6 \cdot 75 - \frac{9 \cdot 73}{20}(6 \cdot 75 - 5 \cdot 75) = 6 \cdot 75 - 1 \times \cdot 487$	$= 6 \cdot 26$
2nd	,,	.. ..	$= 6 \cdot 80$
3rd	,,	.. ..	$= 7 \cdot 36$
4th	,,	.. ..	$= 7 \cdot 92$
5th	,,	.. ..	$= 8 \cdot 48$
6th	,,	.. ..	$= 9 \cdot 07$
7th	,,	.. ..	$= 9 \cdot 67$

Wind Pressures.—The wind pressure on each portion according to the formula from which the table is constructed will be $\log p = 1 \cdot 125 + 0 \cdot 32 \log (h+g) - 0 \cdot 12 \log w$, where g is height of set-off in question above ground line, and h centre of pressure as in last paragraph.

Above 1st set-off,
$$\begin{aligned}\log p &= 1 \cdot 125 + 0 \cdot 32 \log (129 \cdot 73) - 0 \cdot 12 \log (6 \cdot 26) \\ &= 1 \cdot 125 + 0 \cdot 32(2 \cdot 1130404) - 0 \cdot 12 (\cdot 796574) \\ &= 1 \cdot 125 + \cdot 6761729 - \cdot 0955888 \\ &= 1 \cdot 7055840\end{aligned}$$

		$\therefore\ p = 50 \cdot 76$
Above	2nd set-off	,, $= 48 \cdot 89$
,,	3rd ,,	,, $= 47 \cdot 10$
,,	4th ,,	,, $= 45 \cdot 22$
,,	5th ,,	,, $= 42 \cdot 83$
,,	6th ,,	,, $= 40.50$
,,	7th ,,	,, $= 38 \cdot 00$

AREA OF DIAMETRAL PLANES.—The areas of the diametral planes above each set-off will be $d = \frac{1}{2}(D + d)H$ where $D =$ diameter at set-off, $d =$ top diameter, $H =$ whole height above set-off.

1st set-off	$= \frac{1}{2}(6 \cdot 75 + 5 \cdot 75)20$	$= 125$	sq. ft.
2nd ,,	$= \frac{1}{2}(7 \cdot 75 + 5 \cdot 75)40$	$= 270$	,,
3rd ,,	$= \frac{1}{2}(8 \cdot 75 + 5 \cdot 75)60$	$= 435$	,,
4th ,,	$= \frac{1}{2}(9 \cdot 75 + 5 \cdot 75)80$	$= 620$	,,
5th ,,	$= \frac{1}{2}(10 \cdot 75 + 5 \cdot 75)100$	$= 825$	,,
6th ,,	$= \frac{1}{2}(11 \cdot 75 + 5 \cdot 75)120$	$= 1050$	,,
7th ,,	$= \frac{1}{2}(12 \cdot 75 + 5 \cdot 75)140$	$= 1295$	,,

BENDING MOMENT DUE TO WIND PRESSURE.—The bending moment due to wind pressure above each set-off, taking co-efficient for circular chimney as $\frac{\pi}{4}$, will be $\frac{\pi}{4} p\ a\ h$.

1st set-off $\quad \dfrac{\cdot 7854}{2240} \times 50 \cdot 76 \times 125 \times 9 \cdot 73$

$= 18 \cdot 52$ ft.-tons.

2nd ,, $\quad \dfrac{\cdot 7854}{2240} \times 48 \cdot 89 \times 270 \times 19 \cdot 00$

$= 75 \cdot 24$ ft.-tons.

3rd ,,	$= 172 \cdot 10$ ft.-tons.
4th ,,	$= 307 \cdot 48$,,
5th ,,	$= 481 \cdot 25$,,
6th ,,	$= 683 \cdot 80$,,
7th ,,	$= 911 \cdot 46$,,

STRESS DUE TO BENDING MOMENT.—The stress due to bending moment only, will be $\frac{M}{Z}$, thus—

1st set-off $\quad \dfrac{18 \cdot 52}{19 \cdot 65} = 0 \cdot 94$ tons per sq. ft.

2nd ,, $\quad \dfrac{75 \cdot 24}{35 \cdot 10} = 2 \cdot 14$,, ,,

3rd ,, $\quad \dfrac{172 \cdot 10}{55 \cdot 20} = 3 \cdot 11$,, ,,

4th ,, $\quad \dfrac{307 \cdot 48}{80 \cdot 42} = 3 \cdot 82$,, ,,

5th ,, $\quad \dfrac{481 \cdot 25}{111 \cdot 43} = 4 \cdot 31$,, ,,

6th set-off $\frac{683 \cdot 80}{148 \cdot 91} = 4 \cdot 60$ tons per sq. ft.

7th ,, $\frac{911 \cdot 46}{185 \cdot 28} = 4 \cdot 91$,, ,,

Maximum Pressures.—The maximum compression on the leeward edge of chimney at each set-off under the full theoretical wind pressure may now be obtained by the formula $K = m + \frac{M}{Z}$ and the tension on the inner edge $k = m - \frac{M}{Z}$.

			Tons per sq. ft.	
1st set-off	$1 \cdot 01 \pm 0 \cdot 94$	=	$1 \cdot 95$ comp.,	$0 \cdot 07$ comp.
2nd ,,	$1 \cdot 45 \pm 2 \cdot 14$	=	$3 \cdot 59$,,	$0 \cdot 79$ tens.
3rd ,,	$1 \cdot 91 \pm 3 \cdot 11$	=	$5 \cdot 02$,,	$1 \cdot 20$,,
4th ,,	$2 \cdot 34 \pm 3 \cdot 82$	=	$6 \cdot 16$,,	$1 \cdot 48$,,
5th ,,	$2 \cdot 79 \pm 4 \cdot 31$	=	$7 \cdot 10$,,	$1 \cdot 52$,,
6th ,,	$3 \cdot 16 \pm 4 \cdot 60$	=	$7 \cdot 76$,,	$1 \cdot 44$,,
7th ,,	$3 \cdot 53 \pm 4 \cdot 91$	=	$8 \cdot 44$,,	$1 \cdot 38$,,

The safe load on the material according to the limits laid down being 8 tons per sq. ft., the result shows a trifle over, but not sufficient to necessitate any alteration in the design.

Cap and Base.—No account has been taken of the weight of cap nor of the extra surface it exposes to the wind, but the effect of these will be so slight that the stability will not be affected thereby. The part immediately above ground will usually be in the form of a square pedestal externally, with cornice, plinth and base ; this will add considerable sectional area at the lowest set-off, reducing the maximum pressure but increasing the whole load on foundations.

No Tension on Inner Edge.—If tension is not to be permitted on the inner edge, then we must find the maximum wind pressure permissible by the formulæ $l = \frac{3D^2 - d^2}{8d}$ (d being inside diameter), and $p = \frac{W(\frac{1}{2}D - l)}{hH\frac{1}{2}(D + d)}$ (d being top diameter).

Then $l = \frac{3 \times 12 \cdot 75^2 - 6 \cdot 75}{8 \times 12 \cdot 75} = 4 \cdot 33456$ and

$p = \frac{726494 \cdot 86(\frac{1}{2} \times 12 \cdot 75 - 4 \cdot 33456)}{61 \cdot 74 \times 140(12 \cdot 75 + 5 \cdot 75)} = 18 \cdot 54$ lb. per sq. ft. as the mean effective pressure over the whole area, but being cylindrical the equivalent normal pressure on a plane surface would be $\frac{18 \cdot 54}{0 \cdot 7854} = 23 \cdot 6$ lb. per sq. ft., or according to Rankine's co-efficient $\frac{18 \cdot 54}{0 \cdot 5} = 37$ lb. per sq. ft.

Summary.—It will thus be seen that, unless extraordinary means are taken to secure stability beyond the allowances that have been made in the design, a wind pressure varying from

38 to 50·76 lb. per sq. ft. will cause a maximum compression of 8·44 tons per sq. ft. and a maximum tension of 1·52 tons per sq. ft., both being within the safe limits of the material, but that if no tension is to be allowed on the inner edge the wind pressure must not exceed an average of 23·6 lb. per sq. ft. or 37 lb. (according to the co-efficient taken) against a normal plane surface.

Prof. Unwin says in " Bridges and Roofs," p. 119, " We are in this country visited annually by gales, singularly constant in their maximum force, amounting to from 20 to 25 lb. per sq. ft. on a surface perpendicular to their direction. More rarely cyclonic storms sweep over the country, during which still higher pressures are registered. A pressure of 30 lb. was registered during the *Royal Charter* storm ; one of 33½lb. was observed at Greenwich in the storm preceding the fall of the station roof at Manchester. Higher pressures still, up to as much as 55lb., have been recorded at various times, but the accuracy of these observations is more doubtful. We shall probably allow margin enough for the worst contingency, if the maximum pressure of the wind is assumed at 40 lb. per sq. ft. of a surface perpendicular to its direction."

CONCRETE BASE.—The size of the concrete base will depend to some extent upon the nature of the soil, but it must be wide enough to avoid any risk of tilting under maximum wind pressure. This may be calculated as follows, assuming the concrete base to be 24ft. square and 6ft. deep.

Weight of shaft	..	726,495 lb.
,, ,, plinth	say	83,628 ,,
,, ,, footings	,,	163,632 ,,
,, ,, concrete	,,	414,720 ,,
		1,388,475 ,, =say 620 tons.

Then $m+\frac{M}{Z}=\frac{620}{24\times 24}+\frac{911\cdot 46}{\frac{1}{6}\times 24^3}=1\cdot 472$ tons per sq. ft maximum compression and 0·681 tons per sq. ft. minimum compression on the earth below the concrete.

PROTECTION FROM LIGHTNING.—The lightning conductor should consist of a coronal or copper band round the top of chimney, with copper needles 6in. long fixed at intervals of 3 or 4ft. the points being platinized, gilded, or nickeled to prevent corrosion. The main conductor should be not less than 1in. × ¼in., securely attached to the coronal by a clean metal to metal connection, and be carried down side of shaft without insulation but held by projecting holdfasts and clips every 4 to 6ft. The lower end should be carried down 2ft. under the ground and 10ft. away from the base, riveted and soldered to a sheet of copper 4½ sq. ft. area, $\frac{1}{1}$ to ⅛ in. thick and embedded in moist earth or coke breeze. A tube well, as adopted by Mr. Killingworth Hedges, forms the best earth terminal when there is any doubt about the moisture round the copper plate being permanent.

COMPLETION OF DESIGN.—The design may now be completed as shown in the plate.

COST OF CHIMNEY.—The cost of building a tall brick chimney shaft is approximately 1*s*. 3*d*. to 1*s*. 6*d*. per cub. ft. of the solid materials, labour alone being 4d. to 6d. per cub. ft., but much of course depends upon locality, quality of materials and cost of labour.

ALPHONS CUSTODIS CHIMNEYS.—The Alphons Custodis Chimney Construction Co. have built a large number of tall chimneys in America and England, their speciality being radial perforated bricks which appear to have every advantage but that of weight. Weight being one of the elements of stability, its reduction can only be compensated for by increase of one or more of the other elements, such as batter of shaft, diameter at base, or the tensile and compressive strength of bricks and jointing material. This company claim that the strength of their brickwork enables them to design very economical and efficient chimneys, but one would like to learn a little more about the wind pressure they are capable of resisting.

IMPROVING AN OLD CHIMNEY.—A chimney not powerful enough for its work may be improved by lengthening, or by the application of a moderate forced draught, such as the Meldrum system of steam jets in a closed ash-pit. This system can also be made powerful enough to do the whole work with only a short iron shaft, but iron or steel shafts are very perishable and brickwork is worth the extra cost, particularly as a tall chimney discharges the foul gases of combustion at a better height for dilution by the atmosphere. The importance of the latter point will be understood from the fact that the boilers described above would discharge about 40,000 cubic ft. of carbonic acid gas per hour into the atmosphere.

CLASSIFICATION OF WIND FORCE.—The classification by different writers of the force of the wind varies considerably. The following is a fair average :—

Description.	Velocity in miles per hour.	Approximate corresponding pressure lb. per sq. ft.
Barely perceptible wind ..	$2\frac{1}{2}$	$\frac{1}{32}$
Light breeze	5	$\frac{1}{8}$
Pleasant breeze	$7\frac{1}{2}$	$\frac{1}{4}$
Good breeze	10	$\frac{1}{2}$
Strong breeze	15	$1\frac{1}{8}$
High wind	20	2
Half gale	30	$4\frac{1}{2}$
Strong gale	40	8
Whole gale	50	$12\frac{1}{2}$
Great storm	60	18
Hurricane	80	32
Violent hurricane	100	50

By Smeaton's formula $p = \dfrac{V^2 \text{ miles per hour}}{200}$

Discussion.

The **Chairman** said that he had great pleasure in proposing a vote of thanks to Mr. Adams for the very elaborate explanation which he had given of methods of designing tall chimneys.

The vote of thanks was seconded by Mr. Etchells, and carried.

Mr. Henry O'Connor communicated the following remarks in writing :—

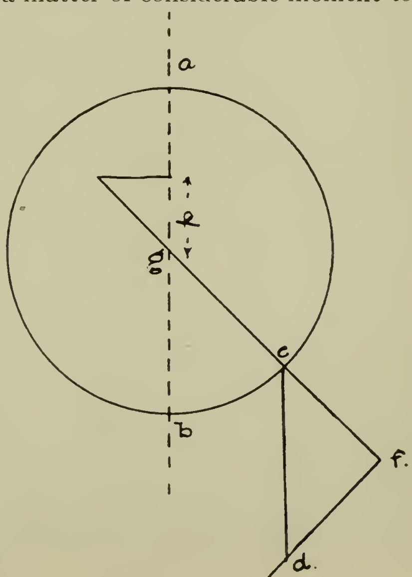
The author refers to the size required for various boilers, but as such chimneys are used for many other purposes, the amount of draught obtainable appears to me to be the most important question. To obtain this it is necessary to know the temperature of the flue gases and then to compare their weight with that of the air, thus :—

1 cubic foot of air at 30in. barometer and 60° F. weighs 0·0763 lb., and varies as its absolute temperature, so that at 600° F. (which we may take for our example as the heat of the chimney gases)—

$$\frac{0 \cdot 0763 \times (460+60)}{(460+600)} = 0 \cdot 0374$$

Then, $0 \cdot 0763 - 0 \cdot 0374 = 0 \cdot 0389$ lb. per foot height per square foot area of chimney, or for a draught of 1in. of water $\frac{5 \cdot 21}{0 \cdot 0389}$ = say 134ft. = height of chimney required. Approximately this works out at $0 \cdot 0075 \times$height of chimney in feet = draught in inches of water.

As regards the question of the wind pressure on a circular object, this has always been a matter of considerable moment to designers of gasholders ; and, as Prof. Adams states, there have been many multipliers suggested. I have used the figure 0·5, especially after reading Bancroft's notes on this point, which may be expressed shortly as follows :—



Let $dc = p$, force of wind acting parallel to the diameter $b\ a$. Resolve this into its component parts acting at right angles to one another at the point c, one of them, $f\ c$, being a normal to the curve ; we then have $f\ c$ as representing the force of the wind acting towards the centre of the circle, and $f\ c = p \cos\theta$ (θ = angle $d\ c\ f$). Resolving this force $f\ c$ at the

point g, so as to measure the effective force exerted in the direction g, and parallel to the wind, we have the effective pressure $P = p \cos^2\theta$. This angle $d c f$ ranges from 0° to 90°, and taking a sufficient number of angles, we obtain $\cos^2\theta =$ about $0 \cdot 5$, therefore mean effective pressure of wind against semicircumference $P = 0 \cdot 5 p$.

With reference to the note on wind pressure given by Molesworth in the 24th edition, dated 1899, which I have, on page 438 the multiplier is there given as $0 \cdot 5$ for round chimneys, but, like Prof. Adams, I know that in some previous edition this was given as $0 \cdot 75$ as I have included this multiplier in the list given in my "Gas Engineer's Pocket Book," where wind pressure on cylindrical gasholders is touched upon.

Mr. E. F. Etchells opened a discussion on the paper. He said that Professor Adams was giving papers on engineering subjects while many of the gentlemen now present were only investigating the lateral stability of a cradle, and he was still busy distributing information with a lavish hand. Papers by some authors had promising titles, but were disappointing, but they might always be sure that, in the case of Prof. Adams, they would get a practical paper which they could keep by the drawing-board and which would be helpful to them in carrying out work.

With regard to the diagram giving the height of a chimney in terms of coal consumption, it should be particularly noticed that it was for a certain number of tons a week for 56 hours a week. In fact, the 56 was as important as the number of the tons because they might get three conditions. Either the boilers might be working continuously with a uniform load, such as in pumping water into a reservoir, or there might be a working day of eight hours with a uniform load during that time, as in the case of an ordinary manufactory, or there might be a case in which there was a working day of from eight to twelve hours with the engine working at high pressure part of the time. In generating stations, for instance, there were certain hours during which the load was high. All those conditions would in turn affect the height of the chimney. Therefore it was very necessary for the engineer to keep in mind the number of hours as well as the number of tons.

With regard to the sectional area of the chimney several rules were given, A, B, C, and D, but perhaps another could be given and called E, because many chimneys had been put up from very carefully calculated formulæ for the sectional area, and the designers had apparently been utterly oblivious of the fact that further boiler capacity might be required at some later period. Therefore it would be desirable to make some allowance for their future needs. The chimneys need not be built too big at first, but they should have a sufficiently wide diameter and be made thick enough, so that at some future date additional brickwork

could be added on the top for the purpose of increasing the draught of the chimney.

He wholly agreed with the statement with regard to wind pressure, in which the author said that a pressure of 56 lb. a square foot would be generally quite safe. But the author went on to say that half of that pressure would be sufficient in many cases, and with regard to that statement it would be desirable to look carefully at the conditions which applied in a case which he had in his mind, where a chimney standing in an inner court rose to a height of about 120ft., some 80ft. of which was sheltered on all sides. In that case certainly a lower pressure could be allowed for a portion of the shaft. In a big city the high chimneys stood above the general level of the buildings, and the general roof level of the central part of the city might be anywhere from 30 to 40ft. above the ground level. They had to bear in mind that the existence of so many buildings practically made a new ground level for the purpose of the estimation of wind pressure.

A reference had been made to a formula which was given by the author in a paper on wind pressure on roofs read before the Society of Architects in 1893. He had not had an opportunity of referring to that paper, but he imagined that the formula there given was not the same as that printed in the present paper, but would be in the following form :—

$$F. \ (\sin \theta)^{(1 \cdot 84 \cos \theta - 1)}$$

The author had stated that a chimney cap or cornice must not, according to the London County Council rules, project more than the thickness of the brickwork upon which it rested, but he believed that the law had now been amended in that particular, and cast iron caps could have a greater projection if desired. For their information he added that most of the rules governing chimneys would be found in Section 65 of the London Building Act of 1894. It was interesting to note with regard to the diameter of the base of a chimney that, while the present Building Act specified that the width of a shaft at the base, if square on plan, must be at least one-tenth, and if circular on plan at least one-twelfth, of the total height, the previous Act, that of 1855, allowed for an octagonal chimney which was intermediate in height between the circular and the square.

The author had mentioned hoop iron galvanised, or painted with cement wash, being used at intervals of 5ft. in height. That was sometimes done, but after the cement wash was laid on the iron, the iron lay on the ground for days, and the cement wash dried off or flaked off. There were also many cases to show that lime mortar would attack steel and not preserve it to the same extent as Portland cement mortar. In the case of one of the big buildings in London, the steel joists were coated with cement wash, the building was left for about three weeks, and the rain came

and washed off a great deal of the cement, so that there, again, there was not the protection which one could have desired.

With regard to the loads given on materials in compression, he noticed " blue brick in cement, 12 tons." That was in accordance with the latest amendment of the London Building Act, but stock bricks would not be allowed to be used under the General Powers Act of 1909 unless the stress was reduced to 8 tons per square foot in lieu of the 10 tons given in the paper. That figure was arrived at by taking the average of a great many authorities.

As to the tensions of certain mortars, the factor of importance was the adhesion between the mortar and the brickwork. In the case of cement the adhesion was very often quite equal to the tension. In lime mortar it was very rarely so, and he had known scores and scores of cases of bricks lifted off by hand—bricks which had been merely set in lime mortar, which had practically no adhesion. The adhesion would depend upon the roughness and porosity of the brick, the capacity of the brick for taking up water, and the amount of water used by the bricklayer at the time of laying. All such factors were outside the control of the architect or the engineer sitting in his office ; and he would urge that engineers should not take into account either the adhesion of the mortar to the brickwork or its tenacity. It was true that many chimneys stood by reason of the adhesion or tenacity of the mortar, but that was more or less good fortune, and it was not a thing which they could always ensure, and therefore engineers must not depend upon what might only occur sometimes.

Again, lime mortar set very slowly indeed. Slaked lime was calcium hydroxide, and it absorbed carbon dioxide from the atmosphere, and in the process of time formed a calcium carbonate. Again, in the interior of the brickwork very often the mortar did not appear to set at all. It sometimes dried or powdered ; and, on account of the gases in the atmosphere the lime mortar tended to perish after a time. Here they had a material which only attained tenacity after a period of time, and after a period of time lost its tenacity, and at the maximum its tenacity was not very great. He would, therefore, urge that it was their duty as engineers not to depend upon a factor which was so uncertain.

With regard to the strength of Portland cement mortar, he noticed that 2 tons a square foot was given. That worked out at about 31·2 lb. per square inch. The tenacity was, however, very variable, and Rankine gave the ultimate as only being 33 lb., so it would be seen that there was a very wide range.

Again, even in a cement mortar, the chimney might meet with a very high gale before the cement was properly set, and, therefore, it would be desirable not to put great faith in tension.

There was a useful warning given where the author spoke about the resultant falling within the middle third. Rankine

had shown that the middle third condition also applied to material under the foundations, as the middle third was also a condition consistent with the stability of a plastic material under a concrete block.

With regard to the wind pressure given on page 365, the speaker stated that the Astronomer Royal had on several occasions returned a wind pressure of 30 to 37 lb. per square inch at Greenwich, but that, of course, was over relatively small areas.

With regard to chimneys of perforated radial blocks, referred to on page 386, he had had opportunities of taking the specific gravity of the material used, and calculating the relative stability. The weight of brickwork as given by Rankine and the Royal Engineers' *Aide Memoire*, and Rivington, varied from 125 to 135 lb. per cubic foot. The patent radial system which he had tested worked out at 128 lb. per cubic foot. That was for the solid brickwork, so that it would be seen that the material of which the bricks were made was about the same density as that of the ordinary brickwork. He found that the area of the openings was about 80 per cent. of the circumscribing area. The cube was about 80 per cent. of solid unperforated cubes having the same external dimensions and the weight was therefore about 80 per cent. of the weight of solid brickwork, from which it followed that the moment of stability due to the weight of the shaft was only equal to 80 per cent. of a solid brick shaft.

It was of no use to attempt to increase the stability of a chimney shaft by widening the base and keeping the weight constant. Just as much as they widened the base they increased the area exposed to wind pressure. In one or two cases it had been necessary to increase the thickness of the chimneys built with radial perforated blocks, so that the stability might be just the same as that of a chimney of solid brickwork in conformity with the Acts or regulations in force locally.

He joined with the author in asking for more information still with regard to the superior stability of hollow block chimneys, because he did not think that figures could show it, and, if they were going to allow that the mortar held better because it filled up all the holes of the bricks, then, of course, that tended to abolish the advantages of the hollow construction.

The author, towards the close of the paper, mentioned one of the advantages of a brick chimney. He said : "Iron or steel shafts are very perishable, and brickwork is worth the extra cost, particularly as a tall chimney discharges the foul gases of combustion at a better height for dilution by the atmosphere." He quite agreed with that statement, but he feared that engineers would not always be able to get building owners to agree with it, because in London, as a rule, the millowner lived away from his mill, and he might not care very much about the atmosphere in the neighbourhood of it.

Mr. M. F. Hertel (Alphons Custodis Co.) said that there were some figures in the paper as regarded the weight of perforated radial bricks in Portland cement mortar. The bricks for 1 cubic foot of brickwork alone weighed 95 lb. without the mortar, so that including the mortar it would come at least to the figure of 120 to 130 lb. which was given by the previous speaker.

Then, as regarded the pressure, the firm he represented had made tests with the bricks, and, without deducting the area taken up by the perforations, they got 354 tons compression per square foot. Those tests were made over here. His firm had made tests abroad for the whole brickwork, and they found that they had 185 tons pressure per square foot of brickwork set in Lias lime mortar.

Another point had been raised with reference to mortar. In his opinion, the mortar was the main thing in the chimney, because if anything failed it would be the mortar. A very interesting book was published by the Royal Society of British Architects which gave information regarding pressure, with reference to Leicestershire brickwork and stock brickwork, and also brickwork built with Gault bricks.

In his opinion, ordinary lime mortar was absolutely unsuitable for chimney building, and personally he should never think of building a chimney in lime mortar without adding some cement to the mortar. In Germany, Austria, and Russia the Government regulations were that the mortar must be composed of one part of cement, two parts of lime, and six to eight parts of sand ; so that no chimneys were to be built in lime mortar at all.

There was another very interesting point about the tension which was to be allowed. He had worked out the same chimney, but making the first section 20ft. high and the other section 40ft. high, allowing for the same taper. That gave a maximum pressure of 9·59 tons and a maximum tension of 1·8 tons ; that is to say, by reducing the weight of the chimney by 10 per cent. they only got about 1 ton more pressure and about ½ ton more tension. He was not going to suggest that that was to be allowed for the material chosen, but it showed that the weight was not such an important factor as was suggested. He went further, and he said that in chimneys of very large diameters the weight was a rather unimportant factor ; that is to say, if they put in a lesser weight per cubic foot they got just as good a result as if they put in a greater weight.

He heartily agreed with the author when he said that the construction of chimneys should be left to experts. In building chimneys in all parts of the country he had come across designs in some cases from people who were not architects and who had not built any chimneys, and he could say that in some cases chimneys were designed which would not stand at all. He knew of one case where a chimney 150ft. high was designed with only

$4\frac{1}{2}$in. brickwork at the top. That was designed in Wales for some large works. His suggestion that it was not enough did not meet with any approval.

As regarded ferro-concrete chimneys, the percentage of failures was certainly very great. There was a very interesting ferro-concrete chimney in London which was 250ft. high, and which had an internal diameter of 20ft. and an external diameter at the base of only 23ft. There were also some interesting ferro-concrete chimneys which had been put up in Kent for the Associated Portland Cement Manufacturers. The firm of which he had spoken took up the question of ferro-concrete chimneys about six years ago, and made experiments with them, and he was told that altogether they had put up four ferro-concrete chimneys. It was rather interesting to know that they had practically gone back to brick chimneys, and he was told that they considered that the experience which they had had was not at all satisfactory. Of course, in this country there were only a limited number of ferro-concrete chimneys, but in the United States hundreds of such chimneys had been put up. He was informed that altogether up to the end of 1910, 28 ferro-concrete chimneys were blown down either in course of erection or shortly afterwards.

An interesting point had been raised with regard to the size of chimneys. Leaving theoretical matters out of consideration altogether, and speaking from the practical point of view, if he had been asked to design the chimney described in the appendix to the paper, he should certainly not have made it any smaller. A chimney 125ft. high with 5ft. 6in. to 6ft. internal diameter at the top would have met the case, but if the chimney was made 140ft. high the diameter at the top would not have to be more than 4ft. 3in.

As regarded ventilating the air space or tying the lining into the chimney, he had found that a ventilation space was unsuitable. If the heat was very great, say 1,500° to 2,000°, which in the case of refuse destructor chimneys was very common, the chimneys would invariably crack unless there was an air space of at least an inch and a quarter, or even up to two and three inches between the fire-brick and the common brickwork.

As regarded octagonal chimneys, the point had been raised as to why octagonal chimneys should not be as suitable as circular ones. The only question to his mind was the bonding. Every course of brickwork had a different diameter, and in each course it was necessary to cut eight bricks, which, of course, meant weakness in the chimney.

He would also like to mention some figures which he had collected from his experience regarding chimneys. Assuming that the chimney in question was to be erected in either Germany, Austria, or Russia, in which countries there were Government

regulations, the results would be quite different. Assuming that the chimney was to be erected in Germany, it would be built in three sections, each section 46ft. 8in. high, with a top wall thickness of 10in. and with a bottom wall thickness of 20in. If it was to be built in Austria it would have to be built in four sections, each section 35ft. high, the top section of 10in. wall thickness, the bottom section of 25in. wall thickness. In Russia the two top sections would be not less than 50ft. high and the bottom section 40ft., the wall thickness varying from 11in. to 23in.

He knew of a chimney in this country 150ft. by 6ft. which was in three sections. The top section was 14in. thick and 74ft. high, and the bottom section was 2ft. in thickness.

Mr. J. W. Wilson said that for nearly forty years he had been walking in a spiral direction round a very fine chimney about 300ft. high and 9ft. external diameter, constructed in a very different method from those which had been brought before the meeting by Prof. Adams. In this chimney there was 14in. brickwork at the bottom and 9in. at the top, the set-back occurring one-third of the way up. In this case the South Tower of the Crystal Palace was so constructed as to hold up the chimney, so that it did not come into the category of the important points, or most of them, which the author had brought before the meeting. It was a very fine shaft of brick in cement, built in headers throughout, and it was adapted for the purpose of ventilating, with its fellow stack at the other end in the North Tower, everything at the Crystal Palace in the way of boilers, cooking arrangements, and so on. The Tower was kept steady by the great weight of the water in the tank, which by itself represented 1,200 or 1,300 tons. In addition to that there were many hundreds of tons of material in the tower, but still it swayed slightly in a gale. There had been no crack in the brickwork as far as he was aware. Presumably, if, in a violent gale, the period of oscillation of the chimney happened to coincide with the period of recurrence of the gusts for any length of time, there might, he thought, be some danger to the tower, but such a condition could never arise.

The reason that he mentioned this matter was that on page 372 the author said : " It is important to note that a tall chimney should stand on an independent foundation in order that the settlement or compression of the soil may be uniform." Therefore, he thought that it was worth while to mention what occurred shortly after the chimney of which he was speaking was constructed. It was built about 1853, and subsequently the L.B. & S.C. Railway tunnel was constructed. This tunnel was not exactly under the tower, but it was rather to the north, about 60ft. below the level of the ground, and about the same distance from the chimney, and it was constructed on the old polingboard

system, so that there was bound to be a settlement after the system was withdrawn, which might have imperilled the stability of the chimney. So careful observations were made as the process went on, more as a matter of interest than for anything else; because, if there had been a collapse of the chimney, theodolite observations could not have done much to save it. As a matter of fact there was a settlement of the whole of the South Tower as the tunnel was gradually carried along. It was built on London clay near the top of the hill in virgin soil, and it all went down a small amount, the settlement being rather more towards the tunnel, and the Tower was now 11in. approximately out of the perpendicular. In a chimney 300ft. high that was practically nothing, but as periodically there was a report in the neighbourhood that the Tower was unsafe, he plumbed it occasionally from the top to the bottom and it had never moved since. This case showed how important it was that the foundations of a chimney should be made so that if it settled at the start it should do so as far as possible uniformly. If the South Tower had been built where the foundation on one side was more yielding than the other it might have tilted over on to the Crystal Palace.

There was one form of stack to which the author had not referred, and he would like to ask him a question in reference to it; that was the cavity stack. A year or two ago he was invited to see the destruction of a cavity stack nearly 100ft. high and weighing 200 tons. It was 11ft. square at the bottom, and was built of 14in. brickwork from the bottom to the top. It had a good batter, and right up the centre of it was a shaft 4ft. 6in. square of 9in. work. This was separate from the outer brickwork except just at the top where the two squares joined one another. They were also buttressed together throughout so that there could be no lateral motion of one without the other. At the same time allowance was made so that when the inner shaft expanded from the heat it could move up and down without interfering with the outer shell, the expansion being nearly an inch in the whole height. They were told at the time that many local authorities strongly objected to a cavity shaft. Of course, they understood that there was a loss of weight in a stack of that kind, and that it was built in order to economise bricks, which would affect the stability, but with an extended base such as was usually provided that was a difficulty which could be easily got over. The stack in question had stood very satisfactorily in severe gales, and one would like to know whether there was any theoretical objection to such a design.

Mr. M. R. de Cordova pointed out that the author, on page 364, gave a formula for finding the sectional area of a tall chimney as follows: $\frac{\text{Fire grate area in sq. ft.}}{1 \cdot 5\sqrt{\text{height in feet}}}$, while in "The Builder" of

8th April, 1905, page 365, what appeared to be the same formula was given thus : $\frac{1\cdot 2 \text{ to } 1\cdot 5 \text{ grate area in sq. ft.}}{\sqrt{\text{height in feet}}}$; the latter giving a result 125 per cent. greater than the former. He would be glad if the author would state which formula was correct.

The author stated, on page 365 : " It is not yet definitely settled what is the pressure of the wind upon a plane surface due to a given velocity. . . . When we come to fix the value of these figures against an inclined or curved surface we find much difference of opinion and no sufficient experimental evidence." Here and throughout the paper it was surprising to find no mention of Dr. T. E. Stanton's classic experiments at the National Physical Laboratory. Dr. Stanton gave the pressure-velocity relation* :—

$$P = KV^2$$

where P = pressure in lb. per square foot.
K = a constant = $0\cdot0032$.
V = speed of wind in miles per hour.

While they must agree with the author that no great confidence could be placed in the results of experiments made on very small surfaces whirled in the atmosphere, it was a notable fact that the experiments above referred to were made on planes having areas of 25 to 100 square feet, and it was remarkable that the mean of the values for K obtained from experiments by Dines, Froude, Langley, and (on small surfaces) by Stanton, was $0\cdot0031$, or within 3 per cent. of the result given above. Dr. Stanton's investigations were made with natural winds ; artificial draught or whirling tables not being used in these experiments.

Taking the relations $P = 0\cdot0032V^2$, when allowance for a wind pressure on roofs of 40 lb. per square foot was made (as recommended by Tredgold and mentioned in Prof. Adams's paper on page 385), it was equivalent to allowing for a hurricane having a velocity of 112 miles per hour, and even then the fact that the roof was inclined to the direction of the wind was left out of consideration.

In the paper, again, on page 365, a formula for effective pressure was given as $P = a\,p\,(\sin\theta)^{1.84\cos\theta}$. It would have been more convenient if this formula had been made dependent upon the velocity of the wind rather than upon its pressure, by substituting KV^2 for p in the formula, since it was easier and more usual to measure the velocity of the wind than its pressure.

He found some ambiguity, too, in the definitions of the symbols used in this formula. As he understood the definitions they might be given thus :—

* Collected Researches N.P.L. 1909, p. 183, and Proc.Inst.C.E., Vol. CLXXI., p. 191.

P = total pressure in lb. normal to the inclined plane considered.
p = pressure in lb. per sq. ft. on a plane surface normal to the wind.
θ = angle of inclination of the plane to the horizontal.

If the foregoing were correctly stated, then in a wind of 20 miles per hour, i.e., with $p = 1 \cdot 28$ lb. per square foot, the intensity of pressure normal to a plane inclined at an angle of 60° was 1·12 lb. per square foot, which was 17 per cent. less than the pressure as determined by Dr. Stanton, viz., 1·35 lb. per square foot. With the plane inclined at 45° the formula gave results 20 per cent. less, and, for an angle of 30°, 31 per cent. less than the results obtained experimentally by Dr. Stanton.

However, Mr. Etchells had pointed out that this formula was incorrectly stated in the paper, and this was confirmed by reference to Ewart S. Andrews's "Theory and Design of Structures," on page 49 of which the formula was given as—

$$P_\theta = P_v \, (\sin \theta)^{1 \cdot 84 \cos \theta - 1}$$

where P_θ = pressure on an inclined surface.
P_v = ,, a vertical surface.
θ = angle of inclination of the plane.

Comparing this formula with the two already considered :—

	Pressure in lb. per square foot normal to the inclined surfaces for a wind velocity of 20 miles per hour and angles of		
	60°	45°	30°
Prof. Adams's formula ..	1·12	0·89	0·42
Ditto as corrected.. ..	1·29	1·17	0·84
Dr. Stanton's formula.. ..	1·35	1·13	0·61

Mr. E. S. Andrews, in his book already referred to, supplemented the formula $P_\theta = P_v \, (\sin \theta)^{1 \cdot 84 \cos \theta - 1}$ by a table of co-efficients by which P_v should be multiplied to give P_θ for angles of 5° and from 10° to 90° by increments of 10°. This table showed that when the angle of the plane with horizontal was 60° the co-efficient by which P_v must be multiplied to give P_θ was 1.

For 70° the co-efficient was 1·02
,, 80° ,, 1·01
,, 90° ,, again 1·0

which meant that between the angles 60° and 90° the normal component of a horizontal wind force upon a plane at those angles was greater than the original force. He might mention that Mr. Andrews gave these figures without any comment.

He had worked out the expression $\sin \theta^{\,1\cdot 84 \cos \theta}$, as given by the author, and a comparison with the corrected expression was given by the following table :—

Expression.	$\theta = 5°$	10°	20°	30°	40°	45°	50°	60°	70°	80°	90°
$\sin \theta^{\,1\cdot 84 \cos \theta}$ . .	—	—	0·25	0·33	0·53	0·64	0·73	0·88	0·95	0·99	1·0
$\sin \theta^{\,1\cdot 84 \cos \theta - 1}$	0·125	0·24	0·45	0·66	0·83	0·92	0·95	1·00	1·02	1·01	1·0

From which it appeared that the incorrect expression gave the more rational results!

In the author's empirical formula p was given = the pressure in lb. per square foot on a surface normal to the wind, while Fig. 2 showed $p \sin \theta$, the normal pressure intensity on the plane. Then the total pressure on the area projected upon a vertical axis was $p \times a \sin \theta$. Resolving this (since *intensities* could not be directly resolved) they obtained the result that the total pressure normal to the plane was = $(p \times a \sin \theta) \sin \theta$, whence the intensity was $p \sin^2 \theta$.

He noted that, on page 379, the sectional area of a chimney as given by formula (a) was 14·14 square feet, and for the same chimney by formula (e) was 7·18 square feet, a discrepancy of nearly 100 per cent., and he would be interested to know which of these formulæ gave the most reliable result.

There was but one other point to which he would refer, and that a comparatively unimportant one. On page 371 the author gave the height of the St. Rollox chimney as 450ft., whereas its height was given by Mr. R. J. Hutton* as 435ft. 6in., that of Townsend's chimney being 454ft.

Mr. Robert W. A. Brewer stated that it was evident that the consideration of the design of a tall chimney involved two main factors—first, that sufficient draught should be produced in the chimney, and, secondly, that the structure itself should be capable of withstanding the stresses which were likely to come upon it.

The first factor was not difficult to determine, but the second and most important factor seemed to involve the application of certain figures about which there appeared to be some doubt. On page 365 the author stated that it was not yet definitely settled what was the pressure of the wind upon a plane surface due to a given velocity. He (the speaker) thought that the results of the large number of experiments which had recently been carried out upon this subject, especially with regard to aeroplanes, would be of some assistance in the determination of the stresses which had to be dealt with. He also referred briefly to the experiments of Zahm, to the Eiffel Tower experiments, and to

* *Stability of Chimney Shafts.* Trans. Soc. Eng., 1887, p. 161.

those at the National Physical Laboratory. With regard to the remarks at the bottom of page 365 and the table on page 366, from which it appeared that the intensity of pressure per unit area on the narrow surfaces was greater than on the wider surfaces, this was in direct contradiction to experience obtained in aeroplane practice.

When designing the supporting surfaces of aeroplanes the ratio of the length of the plane to the chord was of some importance, as when the wings were short (which was equivalent to narrow width on a chimney) allowance was made for the fact that a considerable proportion of the air escaped over the wing tips without exerting its usual proportion of pressure. In some designs the surface itself was curved over or provided with suitable surfaces at right angles to prevent the escape of the air away from the tips. In fact, in monoplane surfaces of the Blériot type an enormous loss of efficiency occurred if the fuselage adjacent to the wing abutments was not covered with canvas to prevent air leakage, so that it was evident that shorter surfaces exhibited a lower intensity of pressure than longer ones.

Referring to Fig. 3, it was interesting to note that, between heights of 5ft. and 50ft. from the ground the wind pressure rose in approximately equal intervals, and although at 50ft. the pressure was 38·4 lb. per square foot, on going up another 50ft. the rise of pressure was only 10 lb. per square foot, and on going another 50ft. (to 150ft.) the further rise in pressure was only 6·6 lb. per square foot.

He would ask whether the author could give any figures or particulars relating to ferro-concrete or steel stacks, as he had noted a certain number in this country.

Mr. E. F. Etchells wished to add one point to what had been said by the last speaker. He understood him to say that the pressures which designers of chimneys allowed for were greater than actually occurred. He (the speaker) did not think that that was quite the case taking all the country together, because in the North of England, where the requirements as to chimney construction were not so stringent, there were many cases of high chimneys which had fallen, whereas in the South of England, where the regulations were a little more stringent, the chimneys stood. He thought that the actual pressures which occurred were somewhere between the two. Whatever experiments might be made, Nature itself was the self-appointed examiner in construction, and it threw down all the faulty specimens. The chimneys in the South of England were left standing after a serious gale, but in the North occasionally some of the economical chimneys were to be seen lying along the ground after a similar gale. So designers had somewhere to look to for definite information as to the pressures which were likely to occur.

Prof. Adams's figures as to the reduction of the average pressure over a large surface were based on actual tests and actual facts. Sir Benjamin Baker conducted some experiments at the Forth Bridge, in which the wind pressure on small surfaces was about 28 lb. per square foot, whereas in the same gale on larger surfaces the wind pressure was only about 19 lb. per square foot. That commended itself to reason, for, supposing that a very large area indeed was taken, the wind pressure would tend to drop down towards the ordinary atmospheric pressure.

There was only a wind pressure at all because in one place the barometer was high, and in another place the barometer was low. If both places were taken into calculation it was found that the average pressure was decidedly less than the maximum. It was bound to be so.

With regard to the anomaly of aeroplane pressures, he believed that the reason was as follows :—If the surface in an aeroplane exposed to wind was very narrow it could be stretched more taut, whereas if the surface was a wider one it was flexible and it sagged like a sail. There was a certain amount of ballooning or bellying, and that ballooning, or convexity, or camber increased with the span of the plane, and therefore held the wind, and the greater the ballooning the greater the pressure on the area. He believed that that was the explanation.

With regard to reinforced concrete chimneys, a good paper was given before the Concrete Institute about a couple of years ago, upon which there was a very full discussion, and in which instances were given of a number of shafts which had been erected. He believed that Prof. Adams took part in the discussion of that paper.

Mr. B. J. Belsher said, with regard to what was stated in the paper to the effect that the proper height of chimneys should be ascertained from a given table by knowing the quantity of coal to be burnt, he thought that the method suggested was very unreliable. Some time ago he had to design a tall chimney which had to take the smoke from eight pairs of Babcock boilers. The boilers were 24ft. long and burnt 1 ton of coal an hour. If a 56-hour week was taken (as suggested) that would make 448 tons a week in all, and from the table that was given the height would come out at about 806ft., whereas the chimney which has been built is actually 180ft. high above the ground, and 216ft. high in all from the bottom of the foundation.

With reference to the other rule about making the height of the chimney three times the length of the boiler plus twice the distance of the furthest boiler from the chimney, if that was adopted the height would be 876ft., which, of course, would have been equally absurd.

The author had said : " In many modern power stations

Babcock & Wilcox boilers and Green's economisers are used." It seemed to the speaker that there was not much in the point which followed, viz., " that what was saved in obstruction in the boilers was lost in the economisers." For the chambers containing the economisers are always made so large that the gases which pass through the flues pass through the economiser chamber and around the economiser tubes at a much lower velocity, so that the friction is not so great. He might say that with the economisers, instead of the gases escaping into the chimney at a temperature of about 600° Fahr., they increased the temperature of the water from about 100° to 190° Fahr. for re-feeding the boilers.

The author preferred circular chimneys to octagonal, because of the angles in the latter, but when one remembered that all the internal angles in an octagonal chimney, to which the soot might be liable to cling, were 135°, one saw that there was certainly not much in that point, but, of course, the question of appearance was simply a matter of opinion.

The author said with regard to wind pressure that it was usual to take 56 lb. per square foot to the normal, and he went on to say that even half of this might be sufficient in many cases. Certain speakers had mentioned that buildings all round a chimney sheltered the chimney, but he did not think that any engineer would be justified in assuming that all those buildings were necessarily to stay where they were for ever. One must, in calculating a matter of this kind, allow for the possibility of the buildings being removed. As to what had been said, it might even be necessary to erect some structure in order to protect a chimney from the wind if one of the buildings was taken down, something in the nature of a permanent, substantial hoarding, but it would, of course, be absurd not to contemplate such a contingency.

With reference to pressure on circular chimneys, he saw that the author gave against his name the figure 0·7854 in the table. He (the speaker) should hardly have thought as the figure above given by Bressé was 0·78, that it was quite necessary to add the last two figures, 54, in the table, the difference being insignificant.

In Molesworth the figures given were as follows:—"1 for square; 0·75 for hexagonal ; 0·65 for octagonal ; and 0·5 for round.

He thought that the formula $\frac{\pi}{4}$, given by the author, was one very usually adopted.

The author had stated that the fire-brick lining must be entirely self-supporting, but the speaker said that in large chimneys it was more usual to put at each offset one course of fire-brick headers, building them half in the ordinary brickwork around the inside of the chimney and to build up thereon the $4\frac{1}{2}$in. fire-brick lining, and at each offset repeating the same process. The brick lining was very often carried half-way up the chimney.

Then there was the point about the space between the chimney and the fire-brick lining, and ventilating this cavity. He had found that in brick-lined flues very often the space behind the brick lining was completely enclosed, and that where it was enclosed without being ventilated the result was that the enormous heat in the flues caused the air in the cavity to expand and force its way through the fire-clay joints in the fire-brick lining. He had noticed that over and over again. It looked like a number of thin white lines on the dirty walls, where the flue dust had been blown from the joints by the air in the cavity being forced through them into the flue. In the chimney which he had spoken about eight ventilating bricks were put at the top of each cavity, one on each side of the shaft, so that as the air expanded behind the 4½in. fire-brick lining it found its way direct into the open air outside the shaft. Otherwise the cavities were closed to the inside of the chimney.

The chimney which he had mentioned was built in Lias lime mortar. He agreed with the remarks which had been made about grey lime mortar, but a hydraulic mortar like Lias lime mortar he considered suitable; in fact, it was far more suitable than cement where there was a considerable amount of heat, as would be the case when the economisers were not in use, and the hot fumes went straight through the by-pass flue into the chimney.

He noticed that the table at the end of the paper with reference to the classification of wind forces was practically the same as the table given on page 146 in Hurst. He thought that it was generally accepted by engineers.

Mr. A. J. C. Ewen said that once or twice in the discussion hollow cavity linings and also the matter of cement and mortar had been referred to. Speaking not as an engineer, but as an architect, it seemed to him at first that if one was building a chimney of ordinary height with a cavity one would use cavity ties : but the gentleman who opened the discussion had rather knocked that idea upon the head as far as he (the speaker) was concerned, because, referring to iron bands, he had raised several objections which would probably apply equally to galvanised iron ties in a hollow wall. He took it that if the fire-brick lining was not actually tied and connected at intervals with the main structure of the chimney the wind pressure would, up to a point, affect the outer skin and leave the inner part alone. That being so, a point must arise at which that pressure on the outside would be so great as to come, unexpectedly, as it were, on the thin inner skin, which was entirely self-supporting, and which was only 4½ or possibly 9 inches in thickness at the very outside, and he could imagine that that would constitute a danger to the inner skin.

The author had been asked a question with regard to the cavity. It would help him (the speaker) if when he answered that question he would say exactly what he thought about the skin. If the outer skin, the main structure of the chimney, were constructed in cement, there were, he supposed, comparatively rare occasions upon which there would be any perceptible sway, and in that case a cavity of an inch and a half would probably preserve the inner skin altogether, but if any considerable height of the chimney were built in mortar or cement mortar, then he took it at a certain point danger would arise by leaving the inner skin entirely self-supporting.

Mr. Benjamin Brear said that he was rather surprised that the author had not said something more about ferro-concrete chimneys. He (the speaker) was interested in ferro-concrete chimneys and he had rather thought that the author would have given some little information as to their design. His firm had lately built half a dozen reinforced concrete chimneys, which they contended had the advantages of brickwork, together with lightness and the advantages of steel. He would have been very pleased if the author had given them a little information as to the design of that type of chimney.

The Author, in reply, said that Mr. Etchells had remarked upon the boilers mentioned in the paper being set to work for only 56 hours in the week. The factory under consideration was a factory where the boilers were banked up at night. Of course in a case where the boilers were working 24 hours a day the amount of coal burnt every week would be reduced to the equivalent of 56 hours, because each hour that the boilers were at work they would burn approximately the same quantity of coal per hour, so that burning half the time required the same size of chimney as burning the whole time.

The statement with regard to the wind pressure being 56 lb. which he said was the maximum which need be allowed under any circumstances—and in many cases half of that would be ample—applied to the two extreme cases of an exposed site where the full pressure must be provided against and of a protected site, such as a site among buildings, where a very much lower pressure need be provided for. As regarded the formula for wind pressure the question of -1 being added to the power of the sine of the angle might be made clear by referring to Fig. 2, where by Hutton's experiments the "normal" will be $p \sin \theta^{1 \cdot 84 \cos \theta - 1}$ and the "direct effect" will be $p \sin \theta^{1 \cdot 84 \cos \theta}$ without the -1, as given in the paper.

As to the use of hoop-iron in the brickwork of a chimney in order to increase the strength he mentioned in the paper that it might be painted with cement-wash. Of course it should be

understood that the painting with cement-wash must be immediately before use so that it had not set hard enough to be chipped off before the iron got into place.

With reference to the loads on brickwork given in the table, it was seldom that he was charged with not giving enough margin. It was generally said that he allowed a great deal too much and that he was too conservative in his notions ; but he was quite prepared to reduce the 10 tons to 8 tons, the 8 tons to 6 tons, and the 6 tons to 4 tons. He came across many cases where the higher pressures were in existence and the structures were standing.

As regarded tension of mortar, he believed that the figure given in the paper was only about a third of what was given by some authorities as the safe tension. It was generally given as 50 lb. per square inch for ordinary mortar, which was somewhere about 3 tons to the square foot. He thought that one ton might be considered safe if the bricks had been properly wetted when laid. In every chimney stack, even in a private house, the top courses should be in cement because rain trickling down would carry away the mortar, and the joints failed very much sooner at the top of the chimney than elsewhere, entirely on account of the weather.

Mr. Hertel had described the bricks used by the Alphons Custodis Company as being very strong in compression, and he had given some figures. That might be, but strength in compression was of no use unless there was strength in tension to follow it up. Where the weight was reduced there was less resistance to the wind pressure. Practically if 20 per cent. was taken off the weight, 20 per cent. must be taken off the wind pressure to match it. He was not prepared to accept Mr. Hertel's statements with regard to the great percentage of failures of ferro-concrete chimneys.

Mr. Wilson had made some interesting remarks with regard to the Crystal Palace chimney. He (the author) thought that in that chimney the weak point would be found to be in the compression owing to the thin wall at the base and the great weight of the brickwork above it.

Cavity stacks had been spoken of. He should say that there were two sorts of cavity stacks, one where there was simply a cavity to give the fire-brick lining room to expand without causing cracks in the outer shell, and the other where the chimney shaft itself was carried up with thin material on the inside, and then protected by walls outside that. These required an extended base and had not a very elegant appearance. He had known cases where the fire-brick lining had been actually bonded at intervals to the outer brickwork, but that resulted in the development of cracks because it was not possible to prevent the expansion by heat on the inside being greater than that of the outside.

Other cases had occurred where the fire-brick lining had headers put into it to reach out and touch the outer shell. That was objectionable because it did not allow the fire-brick lining to expand properly. The object of the cavity was to allow for the expansion and nothing else.

Mr. de Cordova had said that he thought that there was a mistake in the formula for finding sectional area of chimney, as it differed from what was given in " The Builder," but he (Mr. Adams) thought that Mr. de Cordova would find that it was correct in the form he had given it. At p. 146 of his " Engineers' Handbook " would be found a collection of formulæ for the comparison of wind velocity and pressure, and at p. 120 of Prof. Unwin's " Bridges and Roofs " would be found the formulæ founded on Dr. Hutton's experiments as given in the paper.

The formulæ for sectional area are all that the writer had found in use, that marked (a) being clearly outside the usual range.

The St. Rollox chimney was 435½ft. from ground line to top of coping, but the total height from foundation was 455¼ ft., so that it was not far out to speak of it as a 450ft. chimney.

Mr. Brewer had referred to modern experiments on wind pressure. He (Mr. Adams) had tried to follow the modern experiments as far as he could get them, and he had not yet found anything of which he could make practical use. The experiments were on comparatively small surfaces and did not seem to him to be quite in agreement among themselves, particularly those dealing with inclined and curved surfaces ; but he was hoping that some day they would get a valuable result from them. Mr. Brewer had said that he (the author) also had taken his wind pressures too high, but he had been fighting against wind pressures for very many years, and he had said that they had no absolute means of comparing wind velocity with wind pressure. He believed that the results had been taken much too high as regarded pressure. For instance 80 lb. per sq. ft. was said to have been observed at Liverpool in 1868, 53 lb. at Greenwich in 1881, while the records of gales during the erection of the Forth Bridge mostly varied between 24 and 12 lb. Wherever he had found the failure of a wall, or a chimney, or a house, or anything of the kind from wind pressure, he had endeavoured to make calculations to ascertain exactly what wind pressure it was that did the mischief, and very few cases had exceeded about 24 lb. to the square foot. The mean pressure over the width which he had given might be contrary to the figures adopted by the aeroplane makers, but they agreed with the experiments made by Sir Benjamin Baker at the Forth Bridge. Sir Benjamin Baker found that on small surfaces the pressure was much greater during the same gale than over large surfaces. On a comparison of those results with others that were

obtained at the time of Hutton's first experiments, there appeared to be some intermediate size which gave the greatest effect. For instance, the very small planes about 3 inches square used on a whirling table on the first experiments gave very low results. With large areas the resulting pressure with the same velocity increased up to the largest size tried at that time. Then when they came to Sir Benjamin Baker's experiments they found the pressure reduced when they came to the very large areas. That was from a few feet square to a very large size indeed, say 300 square feet.

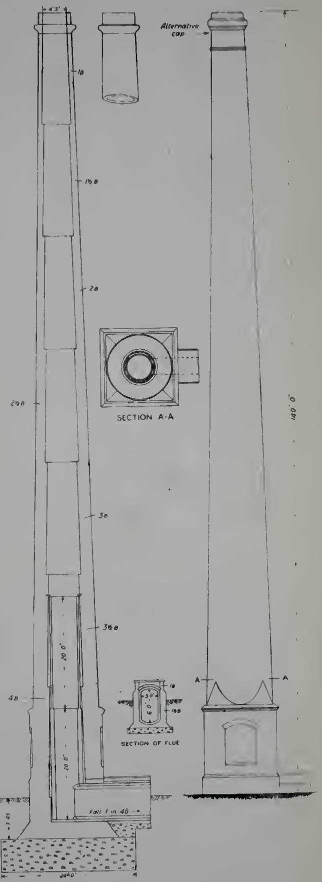
As to ferro-concrete chimneys, the subject of their stability deserved a paper to itself and could not be properly dealt with if mixed up in a paper with brick chimneys. The table on page 386 giving the classification of wind force was not taken from any particular text book, but it was in the same style as tables given in text books. It was an endeavour to average the statements of the ordinary text books upon the velocities of the wind and the corresponding pressures.

Mr. Belsher spoke about the proportion of chimneys to the amount of coal burnt and the mode of burning coal. The proportions given in the paper were for natural draught and ordinary constructions with Cornish, Lancashire or Galloway boilers. The remark about economisers meant this: in the Babcock and Wilcox boilers they had freedom from flues to a large extent, and so a great deal of friction was saved. But when the economisers were allowed to get dirty there was very great obstruction and so there was not very much difference found in the final result whether they had that arrangement or the old Lancashire boilers and the long flues. Mr. Belsher's remarks upon the comparison of circular and octagonal sections were not justified by the statement in the paper. The objection to the octagonal form was the cutting of the bricks to bond the external angles and not the clinging of soot in the interior.

In the figures 0·7854, the two final decimal places had been objected to, but the fault was not his. It was the fault of the decimal system, just as, when they had to deal with the sixteenth of an inch and they wanted to use decimals they might say what was the good of the two final figures? But still they must be put in to make them agree with the original fraction.

Mr. Belsher said that of course he saw the reason for giving four figures, but the author had added two more decimal points to Bressé's value.

Mr. Adams, continuing, said that he did not know the origin of the other formula. Bressé might have given the figures from experiments only. He (Mr. Adams) gave the figures from calculation.


Alternative cap
SECTION A-A
SECTION OF FLUE
Fall 1 in 48
140' 0"
20' 0"
20' 0"
A
A

Mr. Ewen had spoken of cavity ties. A cavity in a brick chimney was a totally different thing from a cavity wall in a house. In the cavity wall of a house they had the main portion of the structure inside to carry the weight of the floors and roof; but they had only a half-brick thickness outside and they had this supported by the wall ties; about one in every square yard. They had practically the same temperature in both walls of the house so that any expansion or contraction would be uniform. In the chimney they had unequal expansion and, therefore, they needed freedom, so that cavity ties would be quite inappropriate to brick chimneys. Mr. Ewen also referred to the effect of wind pressure on the outside of the chimney if the lining was not tied through, causing a bending over and damage to the fire-brick lining. But he thought that as there was a one and a half inch clearance at the smallest part, and that was a long way down the chimney, before the outside could reach over to touch the brick lining it would be inclining very considerably. He did not think that there was any fear of that happening. He was sorry that Mr. Brear was disappointed, but he could not take up architectural design in addition to the other part. To an engineer everything was beautiful if it was adapted to the work which it had to do, and there the engineer must stop. Architectural chimney shafts were sometimes required, and then the engineer and the architect should collaborate to produce the desired result.

As to reinforced concrete chimneys, the first ones were most unsightly, being perfectly cylindrical pipes. Down at Northfleet and in other parts of the country there were some to be seen. But the most recent ones had a slight taper and were certainly passable in appearance. They were good as resisting heat. Very careful observations had been taken and no objection had been found to their use on the score of temperature or weathering or any other cause.

ANNUAL GENERAL MEETING.

The second Annual General Meeting of The Society of Engineers (Incorporated) was held at 17, Victoria Street, Westminster, on Monday, December 11th, 1911, the chair being taken by Mr. John Kennedy (Vice-President).

The chairman announced the result of the postal ballot for the Election of Council and Officers for 1912 and the awards of premiums made in respect of papers published in the JOURNAL during 1911 (see page 411).

The Report of the Council for 1911 was read and adopted (see next page).

Messrs. W. B. Keen & Company were re-elected as Auditors to the Society.

A vote of thanks to the Council and Officers for 1911 was proposed by Mr. H. Laurence Butler, seconded by Mr. Robert W. A. Brewer, and carried unanimously.

A vote of thanks to the Scrutineers, MM. T. J. Gueritte and N. Hoskins, for their services in connection with the ballot for the election of the Council for 1912, was proposed by Mr. J. W. Wilson, seconded by Mr. C. T. Walrond, and carried unanimously, as was a resolution of thanks to the Hon. Solicitors for their services.

REPORT OF THE COUNCIL FOR THE YEAR 1911.

Since the issue of the first annual report of the Incorporated Society the membership has continued to increase, although eight deaths have been reported. The membership of the Society at the date of issuing this report is as follows :—

Hon. Fellows, 24 ; Fellows, 70 ; Members, 349 ; Associate Members, 166 ; Associates, 9. Total, 618, a net increase of 48 in twelve months.

Finance.

The accounts for the current year will be made up and audited as early as possible in 1912 and sent to all the members. The Balance Sheet and the Income and Expenditure Account for the year ending December 31st, 1910, together with the amalgamated balance sheets of the Society of Engineers and the Civil and Mechanical Engineers' Society, as at December 31st, 1909, were printed in the Journal for April, 1911 and sent to all the members. These accounts showed an excess of Income over Expenditure of £65 2s. 6d., and indicated generally that the finances of the Society were in a satisfactory condition. A special effort has been made during the present year to impress upon those who have allowed their subscriptions to fall into arrear, that the Society has a legal right to demand all such sums, and that payment will be insisted upon, if only in the interests of the members who pay their subscriptions promptly and regularly.

Lectures on Engineering Law.

The series of six lectures on "The Law relating to Engineering," by Mr. L. W. J. Costello, M.A., LL.B., was completed in January, 1911. The book is now on sale and has been very favourably reviewed in the technical press. As only a limited edition has been printed members are recommended to apply early for a copy of this book, which one of the reviewers refers to as " the best concise exposition of the law as it affects engineers which has come to our notice." The price to members (only) is 3s. 10d., post free (abroad, Four Shillings).

Affiliation.

The scheme for affiliating student engineering societies to your Society has been met with appreciation by a number of student societies, four of which have become affiliated during

the past year, while others are expected shortly to take advantage of the benefits offered. The names of the four Societies already affiliated are :—

The University of Birmingham Engineering Society.
The Crystal Palace Engineering Society.
The Polytechnic (Regent Street) Engineering Society.
The Queen's University (Belfast) Engineering Society.

Fellowship Examination.

The rules and syllabus of the Examination qualifying for Fellowship of the Society have received during this year the careful consideration of a special committee who have made their recommendations to your Council.

As the result of their work the rules and syllabus of the Fellowship Examination will shortly be issued to all the members.

Council and Officers for 1912.

The report of the Scrutineers, Messrs. T. J. Gueritte and N Hoskins, appointed to examine the ballot lists for the election of Council and Officers for 1912, was read at the Annual General Meeting and showed that the postal ballot of all the members had resulted in the election of the following gentlemen :—

President : John Kennedy.

Vice-Presidents : A. Valon, H. C. H. Shenton, N. Scorgie.

Members of Council : Henry Adams, C. T. Walrond, Percy Griffith, T. E. Bower, H. C. Adams, J. R. Bell, S. Cowper-Coles, H. P. Maybury, B. H. M. Hewett, F. H. Hummel.

Associate Member of Council : E. Scott-Snell.

Hon. Sec. and Hon. Treasurer : D. B. Butler.

Dinner.

The first Annual Dinner of the Incorporated Society was held at the Criterion Restaurant on January 18th, 1911, Mr. Diogo A. Symons (President for the year 1910) being in the chair. The guests included Mr. Alexander Siemens, President Inst.C.E., Hon. F.S.E. ; Col. Sir Edward Raban, K.C.B., R.E. ; Prof. C. Vernon Boys, F.R.S. ; Mr. William Clarke, M.Inst.C.E., Hon. F.S.E. ; and others. Mr. Alexander Siemens replied to the toast of " Kindred Institutions," and there was a musical entertainment at the conclusion of the speeches.

As it was thought fitting that future Dinners should be held during the President's year of office, instead of after its conclusion, the Society's second Annual Dinner was held on May 27th, 1911, at the Criterion Restaurant, the Chairman being Mr. F. G. Bloyd (President for the year 1911). Mr. Alexander Siemens, President Inst. C.E., proposed the toast of " The

Society," which was responded to by Mr. Bloyd. Among the guests were Mr. E. B. Ellington, President Inst.Mech.E., Sir David Gill, K.C.B., F.R.S., Professor John Perry, F.R.S., and Miss Alice Perry, B.E., and Mr. J. W. Jacomb Hood, Engineer-in-chief to the L. & S.W. Railway. The speeches were very brief, the musical programme, which was more extended than before, being much appreciated by the large gathering.

Papers and Premiums.

At the ordinary Meeting on February 6th, 1911, Mr. F. G. Lloyd delivered his Presidential Address, in which he dealt mainly with some aspects of railway engineering, a branch of the profession with which he has long been associated.

Eleven other papers have been published in the Journal during 1911, six of which were read and discussed at the Ordinary Meetings. The Council have awarded premiums as stated below:

The President's Gold Medal to Mr. W. R. Baldwin-Wiseman for his paper on "The Administrative Aspect of Water Conservancy."

The Bessemer Premium, value £5 5s. 0d., to Mr. R. W. A. Brewer for his paper on "Two-stroke Cycle Engines"

The Clarke Premium, value £5 5s. 0d., to Mr. T. J. Gueritte for his paper on "The Mechanical Installation and Up-keep of Permanent Way on Railways."

A Society's Premium, value £3 3s. 0d., to Mr. E. Kilburn Scott for his paper on "Nitrogen Products made with the aid of Electric Power."

A Society's Premium, value £3 3s. 0d., to Mr. F. G. Woollard for his paper entitled "Some Notes on Drawing Office Organization."

The thanks of the Society are due to the following gentlemen (some of whom, being Members of the Council, are debarred from receiving premiums) for the papers they presented during the year:—

Henry Adams: "The Design of Tall Chimneys."

F. G. Bloyd: "The Promotion and Construction of the London and Birmingham Railway."

H. Conradi: "The Colonies as a Field for Engineering Work."

C. R. Enock: "Safer, Quicker and Cheaper Railways, with some proposals therefor."

E. Scott-Snell: "Petrol Air-Gas."

H. C. H. Shenton: "The Protection of Water Supplies."

The Council invite your co-operation in preparing a complete programme of papers to be read at meetings and published in the Journal during 1912. Definite promises of papers should be sent to the Secretary with a statement of the title and general

scope of the proposed paper together with the most convenient date for its reading or publication. A copy of "Instructions to Authors" will be forwarded on application.

MEETINGS.

During the year 1911 there have been 11 Council meetings, 17 meetings of the Examination Committee, and 15 meetings of other Committees, as well as seven Ordinary Meetings (the June meeting being omitted on account of the Whitsun Holiday) the Annual General Meeting (a report of which appears on p. 408) and three vacation visits as follows :—

May 6th. The Festival of Empire Buildings at the Crystal Palace.

June 8th. The Liverpool Street Extension of the Central London Railway.

July 7th. Swanscombe Cement Works, Northfleet.

LIBRARY.

Several gentlemen have kindly given books for the Library during the year, such donations having been acknowledged in the JOURNAL. Offers of recent books on engineering subjects will be much appreciated. The principal British and American engineering periodicals are available for reference in the Reading Room.

ADDRESS TO THE KING.

On the occasion of the Coronation of King George V. a dutiful address of congratulation was presented to His Majesty on behalf of the Society, and was graciously acknowledged.

STATUS PRIZE.

The Status Prize—a premium of books and instruments to the value of six guineas for an essay on "How to Improve the Status of Engineers and Engineering, with Special Reference to Consulting Engineers"—has not been awarded this year, as although several essays were submitted in competition, none of them was considered to be of the necessary standard of merit.

EMPLOYMENT REGISTER.

The number of applications from employers for assistants is increasing as this register becomes more widely known. It would, however, be a benefit if members of the Society would give preference (other things being equal) to men on the Society's register and would refer engineers who require assistants to the Secretary.

Conclusion.

The amalgamation of the Society of Engineers with the Civil and Mechanical Engineers' Society, and the subsequent incorporation of the resulting body has been amply justified by the success which has attended the work of the new Society during the past two years.

The Council desire to express their very hearty thanks to all who have assisted by personal efforts to encourage the development of the Society during the past twelve months.

17, Victoria Street,
Westminster, S.W.

11*th December*, 1911.

INDEX TO TRANSACTIONS, 1910-11.

The date following each title indicates the year of publication, and the page reference is to the volume of Transactions for that year.

NOTE.—A complete index to the Transactions of the old Society of Engineers will be found in the last volume published by that Society, and the volumes of Transactions of the Civil and Mechanical Engineers' Society also are indexed.